REPORT No. 118

THE PRESSURE DISTRIBUTION OVER THE HORIZONTAL TAIL SURFACES OF AN AIRPLANE

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UNIFORM FREE FLIGHT.

SUMMARY.

This work was undertaken by the National Advisory Committee for Aeronautics at the request of the Bureau of Construction and Repair of the United States Navy in order to determine as completely as possible the distribution of pressure over the horizontal tail surfaces of an airplane, and to analyze the relation of this pressure to the structural loads and the longitudinal stability. The investigation is divided into three parts, of which this is the first. This part is for the purpose of determining the pressure distribution over two horizontal tail surfaces in uniform free flight; the second part to conduct tests of similar tail planes in the wind tunnel; and the third part to determine the pressure distribution on the horizontal tail surfaces during accelerated flight on the full-sized airplane.

The general method used in this part of the investigation consists in determining the separate pressures at a large number of points on the tail surfaces of a JN4H airplane, by connecting small holes, opening on the tail surface, to the tubes of a multiple liquid manometer, which simultaneously measures the total number of pressures on one-half of the tail surface. The pressures are recorded by photographing the multiple manometer with an automatic camera which takes an exposure at each condition of air and engine speeds.

These tests in uniform free flight gave the following results:

1. Under no condition did the average tail load exceed 2.3 pounds per square foot.
2. The highest local load on the tail of the JN4H was 11 pounds per square foot.
3. The highest local load on the special tail was 25 pounds per square foot.
4. The torque exerted by the tail about the X-axis ranged from +1,200 inch-pounds (in the direction of the propeller rotation) to −1,600 inch-pounds.
5. The sealing of the crack between the elevator and tail plane has no appreciable effect on the distribution of pressure.
6. The inversion of the standard tail plane (flat surface up) gives a more uniform distribution of pressure as well as improving the stability.
7. The airplane was very stable with the special tail of high aspect ratio even with a center of gravity coefficient of 0.37.
8. The center of pressure travel on the wings, as determined by the integrated tail load, is farther forward than on the corresponding model.

INTRODUCTION.

PREVIOUS WORK.

There has been comparatively little previous work done on the pressure distribution on the horizontal tail surfaces, either in free flight or on models. Perhaps the most notable work is that done by the British on the tail plane of a DH4, but unfortunately the pilot and observer were killed before the work was more than half completed, so that only the left half of the tail plane was explored. Some work has also been done by the Germans on this subject, but they have limited themselves to a few points, so that their results are not at all complete.

SCOPE OF PRESENT INVESTIGATION.

This part of the investigation includes the complete study of the pressure distribution over two horizontal tail surfaces, one a standard JN4H tail plane, and the other of special construction, which was thicker and with a plan form of higher aspect ratio. The pressures were recorded at flight speeds of 45 miles per hour to 100 miles per hour, and at engine speeds of 600, 900, 1,200, and 1,400 revolutions per minute, in order to get all of the conditions that would occur in flight. At the same time various modifications were made in the airplane, such as moving the position of the center of gravity horizontally, and varying the tail plane in angle, section, and plan form. The number of holes on the tail were so numerous (over 200) that the total pressure on the tail under any conditions could be obtained very accurately by integration of the pressure distribution curve. The results are plotted in a large variety of ways in order to bring out as clearly as possible the exact distribution of pressure.

REFERENCES.

Below are given the references to the most important investigations on this subject:

Distribution of the Pressure over the Tail Plane of a DH4 Airplane. R. & M., No. 552, British Advisory Committee for Aeronautics.

Stabilizer and Elevator Pressure Distribution. Report of the Experimental Department, Airplane Engineering Division, U. S. A., December, 1918. Work conducted at M. I. T.

Flosendruckmessungen, Technische Berichte, October 15, 1915.

ACKNOWLEDGMENTS.

The piloting for this research was done by Mr. R. G. Miller and by Mr. E. T. Allen, and the computations and plotting were done by Mr. Gardiner, Mr. Hoot, Mr. Thaden, and Mr. Bennett, all of the Committee's staff.

APPARATUS AND METHODS.

TAIL SURFACES.

The location of the holes in the standard JN tail surface is shown in figure 1 and it is clearly seen that the holes are spaced closely enough to give a very accurate representation of the actual pressure distribution. As this tail was a standard one, it was unfortunately impossible to place the holes in regular rows along the span, necessitating a considerable amount of extra computation. In another test it would be considered advisable to rebuild the ribs, if necessary, in order to obtain an even spacing. The total number of holes on the right-hand side of the tail of both upper and lower surface were connected to the multiple manometer so that simultaneous readings were taken on all of these holes. As soon as the tests were completed on the right-hand half of the tail plane the tubes were removed and placed in the left-hand half and the tests were repeated. Figure 2 shows the layout of the special tail plane which was constructed at the Naval Aircraft Factory. Pressure tubes were attached to both right and left sides of this tail plane, but only one side could be connected to the manometer at a time, as with the other tail. As this tail plane with its tubes was 50 pounds heavier than the standard tail surface, it was necessary to place a considerable amount of lead in the nose of the airplane in order that it might balance in flight, and although it was designed with sufficient strength without external bracing, the usual tail struts and wires were attached as an extra precaution.

In figure 3 is shown the method of connecting the rubber tubes to the pressure holes. A thin brass strip was run along the cap of each rib and the pressure tubes were soldered into this strip of brass; after running through the cap strip of the rib they were connected onto the corresponding rubber tubes. The tubes running to the elevator were carried through reinforced holes at the hinge spars and run through the tail plane to the fuselage with those which were connected to the holes in the tail plane, as clearly shown in figure 4. After the tubes were placed, the tail was covered, care being taken to see that none of the tubes were kinked or that none of them were pierced by the needle when sewing on the fabric. After the fabric had been doped and varnished, the cloth was carefully cut through above each pressure hole so that a clean sharp edge resulted. The tail plane was then placed on the airplane and the tubes run through the fuselage to the manometer as shown in figure 5, great care being taken that none of them was restricted in any way.

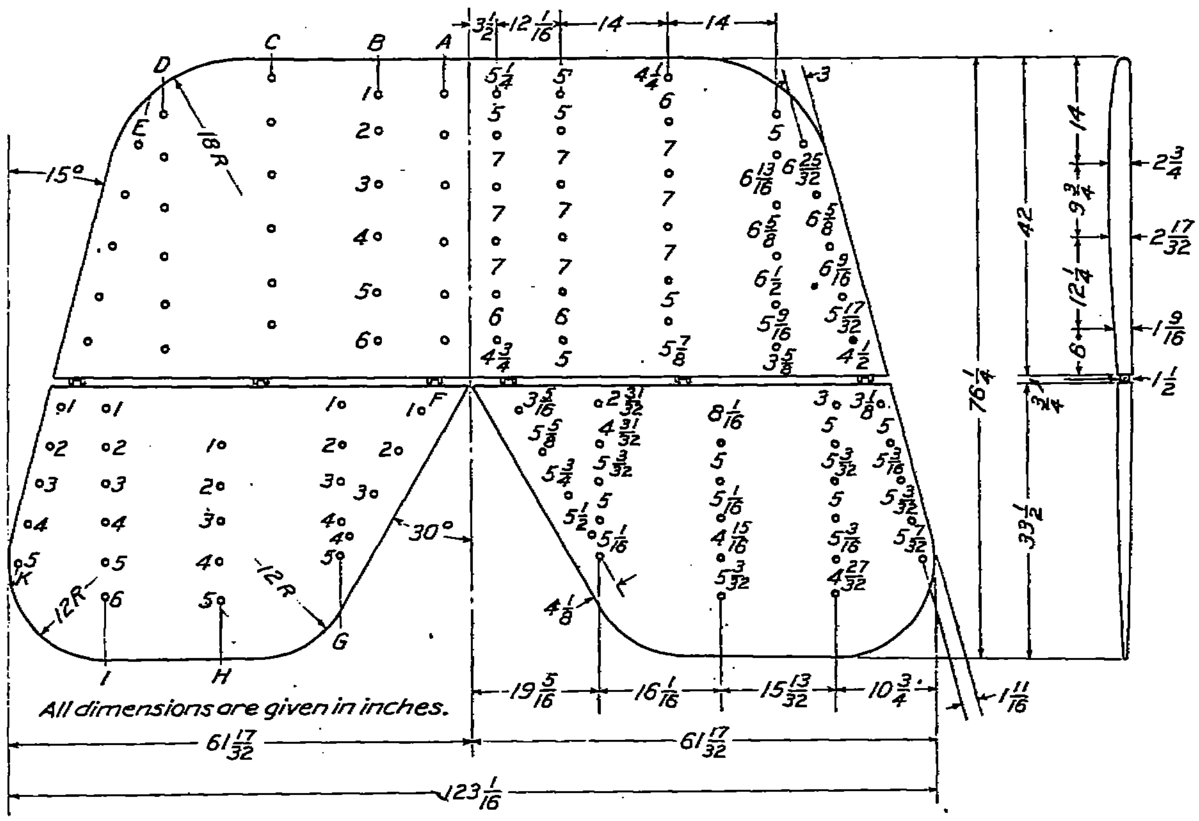


Fig. 1.

PLAN OF JN4H TAIL SURFACE
Showing location of Pressure Holes.

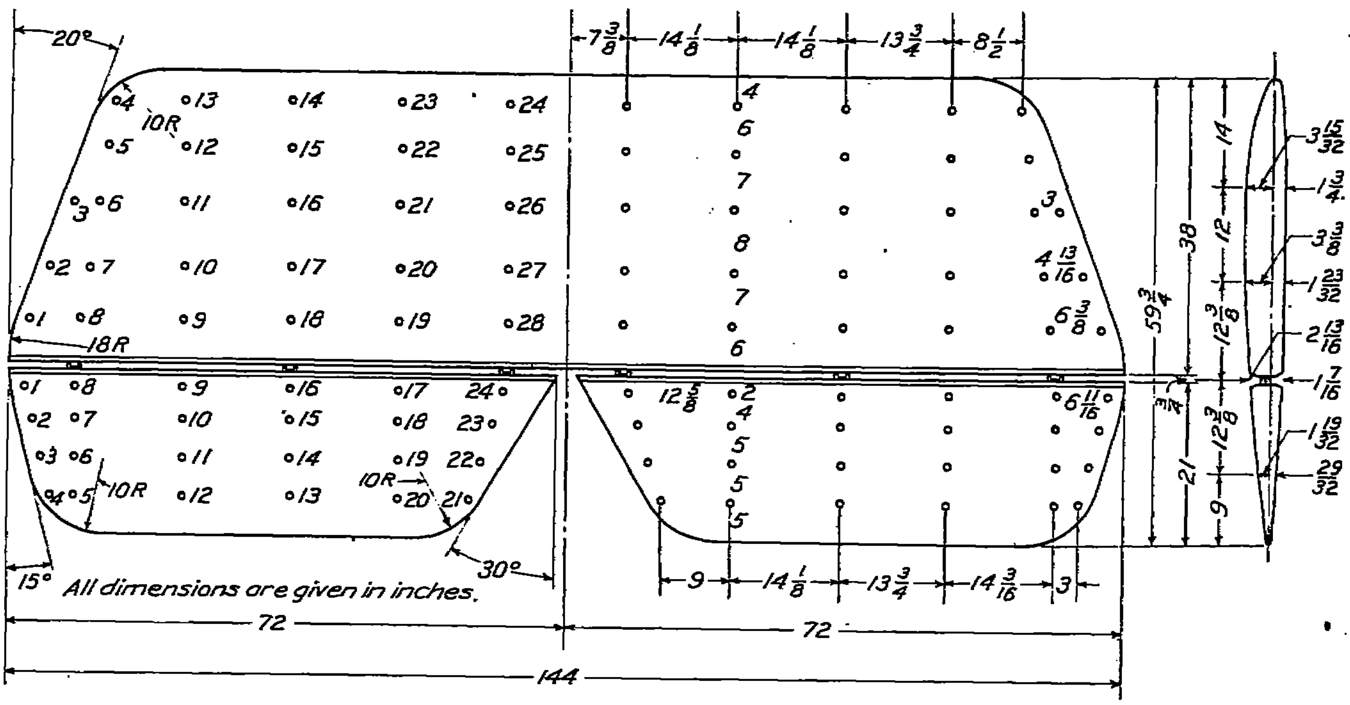


Fig. 2.

PLAN OF SPECIAL TAIL SURFACE
Showing location of Pressure Holes.

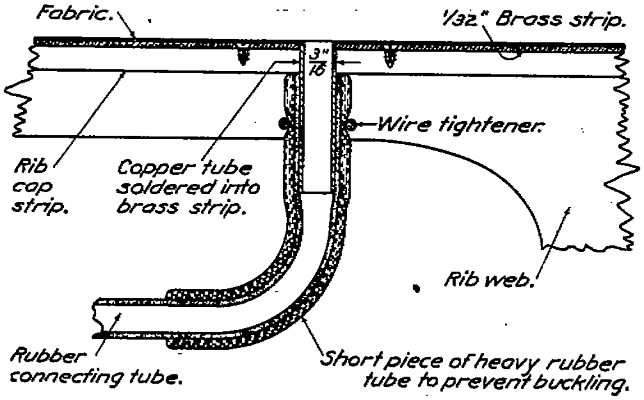


Fig. 3. METHOD OF ATTACHING PRESSURE TUBES TO SURFACE OF TAIL PLANE.

FIG. 4.—Tail plane with tubes in place, before covering.

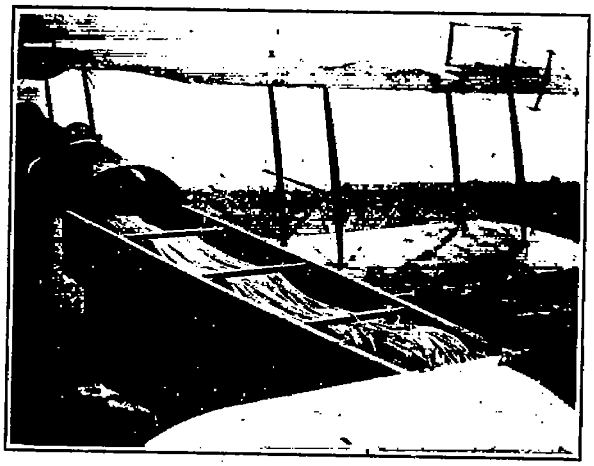


FIG. 5.—Method of connecting the manometer to the tail surface, and showing static head on strut.

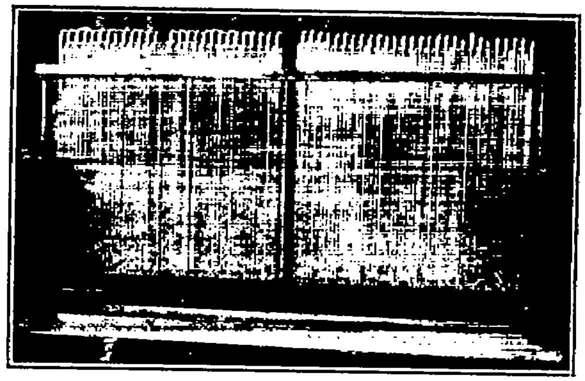


FIG. 6.—Multiple manometer with 112 tubes.

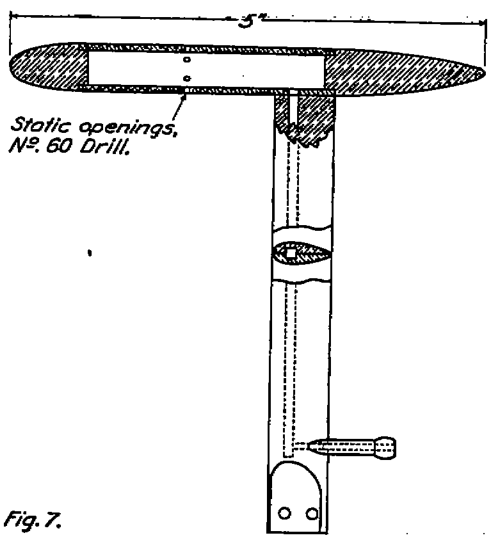


Fig. 7. STATIC HEAD.

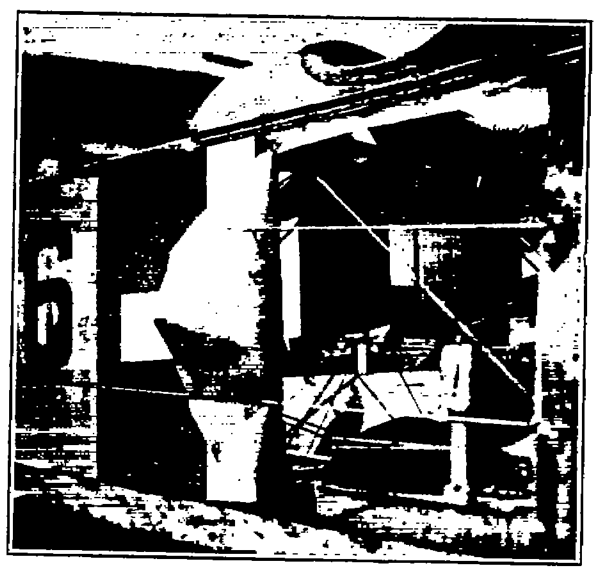


FIG. 8.—Mounting of manometer in the fuselage.

MANOMETER.

The multiple manometer, as shown in figure 6, consists essentially of two end reservoirs connected by a central brass tube out of which rise 112 one-eighth-inch glass tubes, each of their upper ends being connected to a hole in the tail plane. The top of the reservoir and the two end glass tubes are all connected to a static head on the wing strut as shown in figure 7, as it was found that the static pressure in the cockpit was quite different from the true static pressure of the air. In order to make the instrument as compact as possible the glass tubes were cemented into the reservoir at the lower end with plaster of Paris and beeswax. It was found impossible to prevent a slight leakage, but this was so small that it did not cause great inconvenience in the work, and this leakage could evidently be stopped by using some alcohol-proof cement. It was unfortunately impossible to obtain small, thin-walled glass tubing of enough uniformity of bore to avoid the necessity of making capillary corrections, and as these corrections entail a considerable amount of labor in the computation, every effort should be made to obtain tubes of uniform bore for use in future instruments of this type.

The manometer was mounted in a wooden case for protection and a piece of opal glass was placed immediately behind the tubes in order to give an evenly illuminated background against which to photograph. The top of each glass tube was connected by a short rubber tube to a brass connection plate on the top of the wooden case so that all subsequent connections could be made without danger of breaking the glass tubes. The wooden case was mounted in the airplane on the seat rails and pieces of sponge rubber were placed beneath the instrument in order to prevent excessive vibrations from reaching the instrument; however, the mounting was rigid enough so that only very slight relative motions would be allowed. It was found that a fair illumination could be obtained through the fabric of the fuselage, which gave a very even and subdued light, but in future tests it would be advisable to put translucent celluloid windows in the sides of the fuselage. A photograph of the installation of the gauge was taken (fig. 8) by cutting away a portion of the fabric of the fuselage.

CAMERA.

In order to obtain a reading at all pressures simultaneously the multiple manometer was photographed by an automatic camera installed on the seat rail in the fuselage just aft of the pilot's seat. As the space was very restricted it was necessary to use a wide-angle lens, but as this lens was of a high quality the distortion was quite negligible. The camera is shown in figure 9, and consists of a light-tight box containing two large diameter film rolls so that the movement of the film would not appreciably change the diameter of the spools and so change the spacing of the pictures. The spool initially containing the film has attached to it a friction brake, so that at all times the film is kept tight; the other spool contains a large diameter windlass around which is initially wound a cord which runs through pulleys to a smaller windlass at the pilot's seat, one turn of which will move the film along sufficiently for one exposure. In the same way the shutter is connected by wires to a trigger located conveniently for the pilot, so that by a single operation of the trigger the shutter will automatically give a one-second exposure and set itself for the next. A 10-foot length of 3-inch panoramic film was used, and this was sufficient for taking the 22 exposures which completed one run. The mounting of this camera is shown in figure 10.

An exposure of one second was taken in order to give an average reading of each pressure to eliminate the effect of the small oscillations; however, observations and the extreme sharpness of the photographs indicate that the height of the liquid in each tube was very nearly constant. Every tenth tube was painted with a black spot in order to facilitate the measuring of the tubes, and a scale was placed at the center of the gauge in order that the true magnification could be measured when the film was placed in the projection lantern. A section of one of the records is shown in figure 11. It was found necessary in order to secure satisfactory pictures to color the alcohol red and there was some difficulty in finding a coloring matter which would not be oxidized by the denatured alcohol which was used, but finally an analine dye was found which would satisfactorily retain its color.

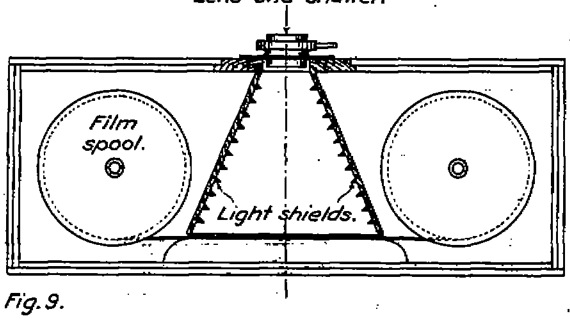


Fig. 9.

TOP VIEW OF AUTOMATIC CAMERA.

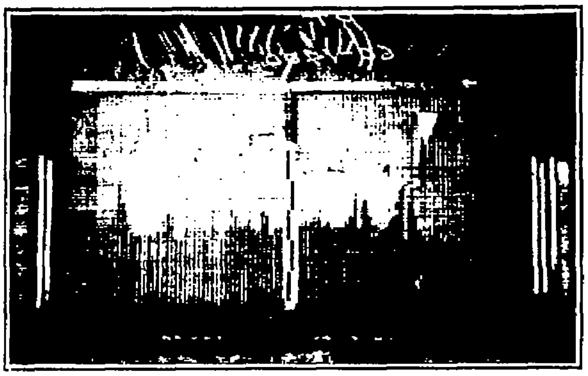


FIG. 11.—A record taken by camera

FIG. 10.—Mounting of automatic camera in airplane.

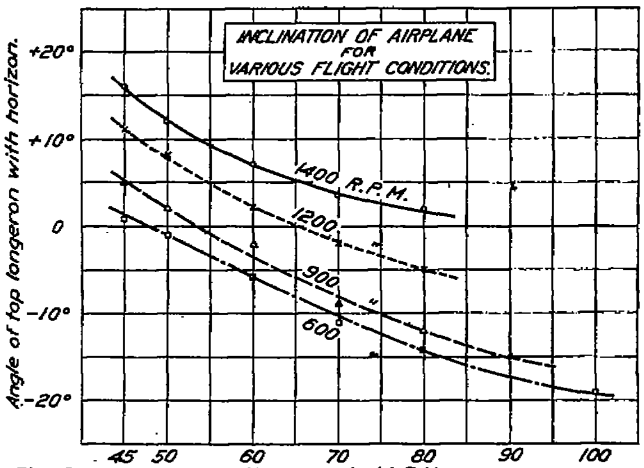


Fig. 12.

PILOT'S PROCEDURE.

All of the runs were made at an altitude corresponding to a density of 0.9 in the following manner: At the start of each flight the altimeter zero was set by the reading of a mercurial barometer so that the desired density would come at a reading of just 3,000 feet. Before each exposure the airplane was climbed considerably above the given height and the exposure was made as the airplane reached the 3,000-foot level, having previously attained a steady condition of flight. In the computations this factor 0.9 does not enter in, as the air speed was not corrected for density, for the same density effect will obviously apply to the air-speed reading as to the surface pressures. There is one exception, however—the effect of the slip stream—which will be a function of the density, and it was for this reason that all the tests were made at a constant density.

METHODS OF READING FILMS AND COMPUTATIONS.

As it was very tiring to read the height of the menisci from the photographic record with a magnifying glass, it was thought best to place the negatives in a projection lantern and throw the image onto a screen at a certain definite magnification. In this way the height of the liquid could be measured with a large scale very quickly and conveniently, using as zero a line scratched across the film between the menisci of the two static tubes. It was also necessary to determine the capillary correction in the same manner, and these corrections were in every case subtracted from the readings. The head of alcohol thus determined was then corrected by multiplying it by factors for the density of the alcohol and the inclination of the tubes due to the longitudinal position of the airplane in flight.

The longitudinal angle of the airplane was determined for each flight speed with a liquid inclinometer, and the results are shown in figure 12. It will be noticed that the angle is only 19° in a 100-mile-an-hour dive, and this would ordinarily be called a steep dive, for the angle is always overestimated in such conditions. The head of alcohol as read was then multiplied by the cosine of the angle of inclination of the tubes from the vertical.

METHODS OF PLOTTING AND INTEGRATION.

The values in true head of water were then plotted along each row of holes in the direction of the air flow, the upper and lower surface using the same base line, so that the planimetered area between them represents the total pressure along that section. A few of these curves are shown in figures 36 to 79. Because of the irregularity of the holes occasioned by structural considerations, it was necessary to cross fair these preliminary curves, thus obtaining pressure sections at right angles to the air flow. These curves are shown in figures 80 to 122, and give the sum of the air forces on upper and lower surfaces. These curves are sections of a solid representing the total load on the tail, and are revolved about their respective base lines into the plane of the tail, so that in the figures an area on the forward (leading edge) side of the base line will represent an upward or positive load. The area under each of these curves was found by planimetering, and by using the values thus obtained as ordinates for a curve drawn parallel with the air flow; the total pressure on the tail is represented by the area under this second curve. The point of action of this pressure was found in each case by integrating this area about the hinge with a mechanical integrator. These curves are shown in figures 123 to 242.

In each figure two vectors are shown, one, marked T, representing the center of pressure of the complete tail surface, and the other, marked E, representing the center of pressure on the elevator alone. In each case the vectors are shown to scale (in position, but not in magnitude), except where they are off of the paper, but the distance of the vector from the hinge is given each time in inches. In the curves representing the total pressure parallel to the leading edge the same system of vectors is used, except that they represent in all cases the force on the complete half of the tail; and the moment of that half about the center line is given in addition to the distance from the center line. The force on the elevator control was found by taking the moment of the pressure on the elevator about the hinge, but as the results were not as reliable nor as easy to obtain as direct force measurements on the stick, no results of this character are plotted in this report.

There is another method of easily obtaining the total load, or the moment about any axis of an irregular pressure surface, which may be termed the plastic method. Let us suppose that a scale model is made of the tail with adjustable pins at the points at which the pressure readings were taken. If each pin is then set at such a height as will correspond to the pressure at that point,

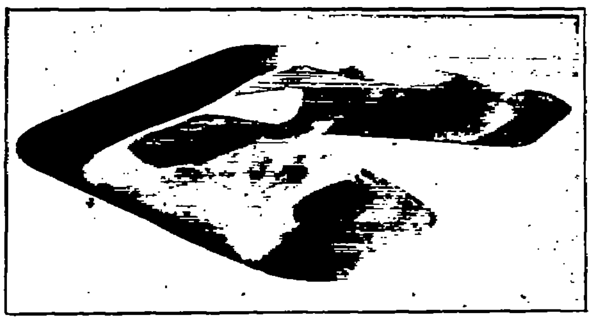


FIG. 13.—Model of pressure surface—Case I—600 r. p. m.; 100 m. p. h. The light-colored material represents down pressure and the dark material up pressure. The region of down load is evident at the leading edge.

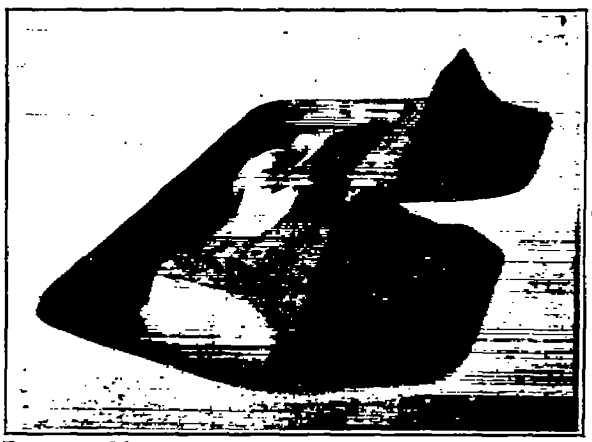


FIG. 14.—Model of pressure surface—Case VI—600 r. p. m.; 100 m. p. h. This shows the very large down load at the leading edge and the sharp peaks of up load at the hinge.

a skeleton of the desired surface will be obtained. By filling the space between the pins with a plastic material—clay or plasticene—and fairing in the surface, which it is very easy to do with a little practice, a solid is obtained which represents the actual load on the given surface.

The total load or its moment may be easily found from this model solid simply by weighing it, or by balancing it about any desired axis, provided the density of the plastic material is known. It is evident that this method is applicable to an irregular spacing of points where a sectional method would be impossible or at least very laborious, and even with evenly spaced holes it is very much quicker than a two-dimensioned method. The plastic method was used in this investigation for only a few cases because of the necessity of obtaining the sectional curves for two-dimensioned reproduction. (See figs. 13 and 14.)

PRECISION OF THE RESULTS.

ERRORS IN READING FILM AND COMPUTATION.

It is possible in nearly all cases to measure the actual head of alcohol from the enlarged negative within the limits of plus or minus 0.003 of an inch. As all the calculations were carried out to the nearest 0.001 of an inch, the computed head should be correct in every case to at least 0.005 of an inch. The areas under the curves were planimetered several times in order to get a correct reading, so that all the area can be considered correct within plus or minus 0.01 of a square inch. An error somewhat larger than this is introduced, however, because of the incorrect representation of the curve between the given points, and this is especially true at the end of the tail plane where the pressure gradient is very steep. As 1 square inch under the final curve is equal to approximately 10 pounds, the total load on the tail will be given to within plus or minus 0.1 pound if the curves are assumed to be correct. The difficulty in drawing a true pressure curve through the given points will, however, considerably increase this error, so that the total load on the tail can not be assumed to be correct to better than one-half of a pound from these causes of error.

ERRORS IN FLIGHT.

The errors due to computation and reading are, however. small compared with the errors inherent in all full-flight work; that is, errors arising from irregular atmospheric conditions. For example, if the airplane happens to strike a bump in the air at the time that the exposure is taken, it may considerably alter the value of the pressure obtained, especially those pressures on the movable portion of the tail plane. For this reason the first runs were repeated in order to check the results, and it was found in most cases that the check run agreed very closely with the original run. The subsequent work was very complete and there was ample chance for checking; as so little change was made in the flight conditions from one run to another, it was not thought necessary to make check runs in every case. The excellent agreement that can be observed between the pressure curves taken under nearly identical conditions leads one to have confidence in the results, as any part that is appreciably in error will be at once shown up by its lack of resemblance to a similar curve.

It will be noted that the points calculated from the total load on the tail in order to obtain the pitching moment due to the wings and body do not lie smoothly on their representative curves and in comparison with wind tunnel results, for instance, they would look rather unsatisfactory; but it should be remembered that all results obtained in full flight are inherently irregular, due to conditions of the atmosphere which can not be overcome, and it is only possible by taking large numbers of readings and averaging them to get a satisfactory mean value. The moment curves check well with one another and the close agreement between the center of pressure travel curves for the different combinations used, all give a good indication of the accuracy of the results. For determining pitching moments, however, the pressure distribution method is not as accurate as the method used by the British where the fuselage was jointed.[1] As all of the readings and the computations have been carefully checked at every step by this method, it is felt that on the whole the results are presented as closely as it is possible to do so.

[1] British Advisory Committee, R. & M. No. 400. "The Full Scale Determination of the Pitching Moments of a Biplane."

SCOPE OF TESTS.

In order to represent as fully as possible all of the conditions that occur in flight on tail planes the following variations in the airplaine were made. It should be noted that in this report the center of gravity coefficient is the distance of the center of gravity from the nose of the mean chord in fractions of the chord. The mean chord is taken at distances from the upper and lower wings which is inversely proportional to their areas; that is, 60 per cent of the gap above the lower wing.

Case I.—On this run the airplane had a standard rigging of 17½ inches of stagger and a center of gravity coefficient of 0.381. This position of the center of gravity is about the standard position for an airplane of this type, and in order to compensate for the lack of a passenger in the rear seat a sand bag was tied to the floor boards in the rear cockpit.

Case II.—In this run the conditions were the same as before except that the sand bag was removed from the rear cockpit and some lead was placed in the nose of the airplane just aft of the radiator. This gave a center of gravity coefficient of 0.326.

Case III.—With the same position of the center of gravity as in the previous case the tail plane was given a negative angle of 1½°; that is, the flat lower surface, which in the previous run was parallel to the longerons, was raised at the rear end in order to give this surface a slope of 1½°.

Case IV.—In this run the conditions of the airplane were exactly the same as in the previous run; the only change being the sealing of the crack between the elevator and the tail plane with flat sheets of celluloid, which we screwed to the tail plane and were allowed to rest by their own weight on the movable portion of the tail surface, smoothly covering up the intervening crack.

Case V.—In this run the stagger of the airplane was reduced to 8½ inches, the tail plane was inverted so that the flat surface was uppermost and parallel to the longerons, also enough lead was placed in the nose of the airplane to give a center of gravity coefficient of 0.244.

Case VI.—In this run the stagger was again 8½ inches, and the center of gravity coefficient, due to the heavy tail, was 0.370. The tail surface was a special one of thick section and high aspect ratio (fig. 2), with its chord parallel to the longerons.

In none of these cases was the airplane very badly out of balance and at all times it could be flown with a fair degree of ease. In the fifth case, however, it was a little difficult to get the tail down in making a landing. It was noticed when flying the airplane with the special tail plane that the longitudinal stability was greatly improved and the airplane flew hands off with both open and closed throttle. This is quite remarkable in view of the rearward position of the center of gravity, and a more complete study will be made in a subsequent report.

RANGE OF AIR AND ENGINE SPEEDS.

For the first five cases the following 22 combinations of air and engine speeds were used each time:

	Revolutions per minute.			
	600	900	1,200	1,400
Air speed	45 50 60 70 80 100	45 50 60 70 80 90	45 50 60 70 80	45 50 60 70 80

In Case VI only the following combinations were used, as it was thought that, taken with the preceding data, the information obtained would be sufficient.

	Revolutions per minute.	
	600	1,400
Air speed	50 60 70 80 100	45 50 60 70 80

GENERAL DISCUSSION OF RESULTS.

The discussion will be mainly confined to the consideration of the actual pressures and to their relation to the structure. Further on the change in load with flight conditions will be analyzed more carefully in respect to airplane stresses and stability. The subject embraced by the report is so wide that it is difficult to keep in mind all of the data at one time, and only by constant reference to the curves can a comprehensive view be obtained.

THE PRESSURE DISTRIBUTION WITH A STANDARD RIGGING OF THE AIRPLANE.

For this run the preliminary curves under all conditions are given in figures 36 to 79. These are given in order to show the pressure distribution as separated on the upper and lower surfaces. A suction is plotted downward and a pressure upward, the upper surface and the lower surface using the same base line. The greatest suction occurs on the lower surface of the tail plane very close to the leading edge. The suction is also large at the very tips of the tail plane, this being due to the raked tip acting in the same manner as a leading edge. There is also a tendency at high speed to have a large suction on the upper side of the elevator, especially near the outer part of the span. At no point, however, on the tail plane did the suction reach a value higher than 1½ inches of water, and as this suction is comparatively very small there should be no fear of stripping the fabric on a well-constructed job.

It will be noticed that the pressure curve on the elevator has a rather definite wave form with a period of about 12 inches. The reason for this is probably that the discontinuity due to the joint between the elevator and the tail plane gives rise to a stationary wave which continues along the surface of the elevator. It will be noticed later that when the crack is sealed up these waves are much reduced, but they are even then in evidence. The discontinuity of pressure at the hinge of the tail plane is in no case very large; in fact, it is much smaller than the results from the model test would indicate. The line of zero pressure used as a base line in a good many cases lies above the pressures on both the upper and lower surfaces, showing that the static pressure in the slip stream is below that of the true static; but this would not, of course, affect the load on the surface which is independent of the base line. It was also noticed that the pressure in the cockpit was from an eighth to a quarter of an inch below the true static.

In order to give a better visualization of the pressures over the surface the total pressure has been plotted in figures 80 to 101 in order to show this more clearly. It is evident that the greatest load occurs on the leading edge of the right-hand side of the tail plane under practically all flight conditions. These curves show very strikingly how great a difference there is between the pressure distribution on the right and left side of the tail plane, so that a pressure distribution comprising only one-half of the tail would be of very little value in determining the total tail load. Some of this difference is undoubtedly due to the fact that the rudder and fins are not symmetrical in flight, but the greater part is due to the fact that the angle of incidence and velocity over the two halves of the tail plane are different, due to the rotation of the slip stream. It should also be noticed that a very large torsional load could be put on the fuselage by not rigging the elevators at the same angle of incidence; that is, if one elevator is several degrees higher than the other it will greatly change the pressure distribution on the tail plane, so that great care should be taken when rigging an airplane to ascertain that the elevators are properly lined up.

In figures 123 to 144 the curves shown represent the total pressure on the tail plane plotted on a section taken parallel to the plane of symmetry of the airplane. These curves are shown, one for the load on the right-hand half of the tail plane, and one for the load on the left-hand half of the tail plane, and the third serves to represent the total load. The most important features shown by these curves are the considerable difference between the right and left half of the tail plane and the large suction at the leading edge of the tail plane.

In figures 243 to 264 are shown curves giving the total pressure on the tail plane on a section at right angles to the X-axis of the airplane. These curves show that the pressure is greatest at the tips of the tail plane and elevators. By plotting the moment of the area of this curve about its line of symmetry it is possible to compute the torque of the tail plane about the X-axis of the airplane, which will be discussed more in detail in a later portion of the report.

An attempt has been made in figure 13 to give a more realistic picture of the distribution of pressure than is conveyed by a set of curves. It is not possible to satisfactorily represent a three-dimensioned figure in two dimensions, but it is hoped that the photographs of these models will aid the reader in grasping the general trend of the tail pressures. The white surface is a plane lying in the tail surface and consequently representing zero pressure. A light-colored plastic material is used for negative pressures (down loads) and a dark material for the positive pressures, and the lighting is such as to show the relief to the best advantage.

It can be stated in general that with the airplane rigged as described above that under no condition in uniform flight are the loads set up by the pressure on the tail plane at all large, the load per square foot on the tail plane seldom exceeding one-half pound per square foot and the maximum reached amounted to only 1¼ pounds per square foot. This load is quite insignificant and amounts to little more than the weight of the tail itself, so that it may be concluded in steady flight that the stresses in, or due to, the tail plane may be considered of quite negligible value. The torque on the fuselage due to the tail plane is, however, considerably larger than has been realized before.

THE EFFECT OF CHANGING THE POSITION OF THE CENTER OF GRAVITY.

In Run II the center of gravity was moved forward and the resulting pressure distribution on the tail plane was found to be similar to those of Case I. The preliminary curves were omitted, as it was thought that they would be of little interest, for they showed no great difference from the curves obtained in the first case. As was expected, moving the center of gravity forward produces a greater negative load on the tail plane. Examination of the curves, however, shows that there is practically no difference in the distribution of the pressure contained in the two cases. A discussion of variation in total load on the tail plane, due to the change in air speed and revolutions per minute of the engine, will be discussed later in relation to their effect on the stability of the airplane; but in general it may be stated that the distribution of pressure on the tail is not appreciably affected by any change of center of gravity position.

EFFECT OF CHANGING THE STABILIZER ANGLE.

Case III is a duplicate of Case II, except that the position of the tail plane has been moved to 1½° of negative angle. Contrary to the case of altering the center of gravity position, the changing of the angle of the tail plane produces a considerable change in the distribution of pressure. This is explained by the fact that the total load on the tail must be the same as before, and as the tail plane is at a greater negative angle the load on this part of the tail plane would be more negative while the corresponding load on the elevator must be more positive, thus necessitating the lowering of the elevators. These facts are confirmed by the greater force that must be applied to the stick when the tail plane is turned to a more negative angle; that is, the ship feels as if it were more tail heavy with a negative tail-plane setting. This change of pressure distribution can be seen more clearly by comparing the curves of total pressure (figs. 145–166) in Case II with similar curves occurring for Case III (figs. 167–188). The curves in figure 15 show this change in load between the tail plane and elevators with a change in tail-plane setting. It is clear from these curves that a negative tail-plane setting of 1½° with the same center of gravity position will shift a load of about 20 pounds from the tail plane to the elevator, and it is interesting to notice that this distance between the different curves is practically constant in amount for any condition of flight. The difference in load, however, between the tail plane and elevator load varies in inverse proportion to the air speed. It may be concluded that a change in the angle of tail-plane setting makes a considerable difference in the distribution of pressure over the tail plane and in general a more negative setting of the tail gives a more negative pressure on the tail plane and a more positive pressure on the elevator.

EFFECT OF SEALING THE HINGE CRACK BETWEEN THE ELEVATOR AND TAIL PLANE.

As model tests indicated that there was a considerable amount of leakage of air through the hinge crack of the tail plane, it was thought that some data of interest might be obtained by taking a run with the crack sealed up. This was accomplished by placing thin sheet celluloid over the crack on both the upper and the lower surfaces so that the resulting surfaces were quite smooth and continuous with any elevator position. Except for a slight tendency to smooth out the wave form of the pressure curve on the elevator, there is no difference between the run with the crack sealed and with the crack open. For this reason only the curves of total pressure are given, in figures 189 to 210, as the other curves were similar to the curves of Run III within the errors of the experiment. The fact that there is no change in the pressure distribution with the sealing of the crack does not show conclusively that sealing the crack has no effect on the efficiency of the tail, for the pressure distribution on a thin surface of this type does not indicate the drag, so that it may be that sealing the crack will considerably decrease this factor.

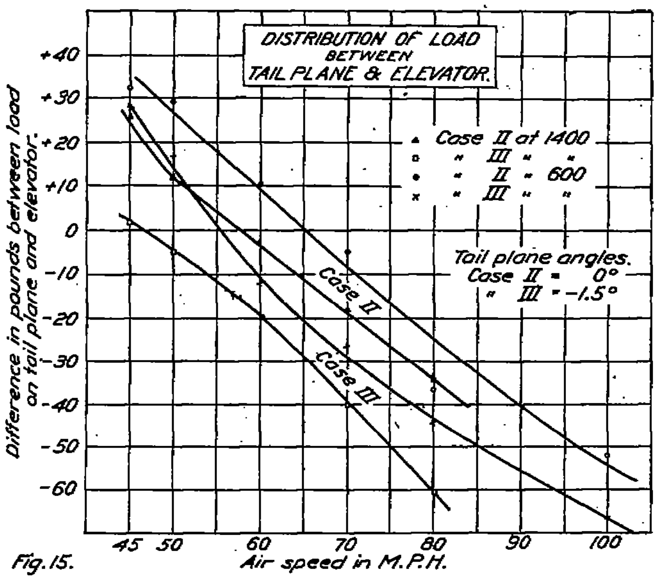


Fig. 15.

THE EFFECT OF INVERTING THE TAIL PLANE.

In this run the tail plane was inverted so that the flat surface was uppermost and parallel to the longerons. As should be expected, this change makes a marked difference in the distribution of pressure and the effect is clearly seen in the curves of pressure in figures 105 to 112. The greatest effect on the pressure distribution in this position of the tail plane is the more even distribution of pressure across the span, especially the elimination of the region of high suction near the tip of the tail plane. Curves of total pressure (figs. 211–232) show that the point of maximum suction is moved back from the leading edge a considerable amount and that the load on the elevator is also moved nearer to the trailing edge. That is, instead of being a sharp peak of suction immediately above the leading edge, as in Case II with the ordinary disposition of the tail plane, in the case where the tail plane is inverted this pressure is distributed fairly evenly over the whole tail plane, reaching its maximum about a third of the distance from the leading edge of the tail plane; so that it would seem that from a structural point of view it would be of great advantage to use this form of tail plane, as it would distribute the load in a more satisfactory manner. As will be shown later, this tail plane also gives a greater degree of stability, and its use is recommended from all points of view.

THE PRESSURE DISTRIBUTION OVER THE SPECIAL TAIL PLANE.

The tail plane shown in figure 2 is of a more modern design and has a rather thick double-cambered section and also a considerably higher aspect ratio. The pressure curves which are given in figures 113 to 122 show that the pressure over the tail plane is greatly altered from that over the ordinary tail plane. The greatest difference is the very high peaks at the leading edge and at the elevator hinge, one up and the other down, which reach very great magnitudes at the higher speeds. This introduces high local loads and a large twisting moment that may seriously stress the tail structure. The cause of this peculiar distribution of pressure may be due either to the thick section or the high aspect ratio, but the former is the more probable cause. A model of this tail at 600 revolutions per minute and 100 miles per hour is shown in figure 14. This twisting about the Y-axis may be quite serious, and the front spar should be made very stiff in thick-sectioned tail planes to prevent a deflection of this member. In one case the moment about the Y-axis was over 600 foot-pounds—an exceedingly large moment, and one that might have caused failure in a less strongly constructed tail surface.

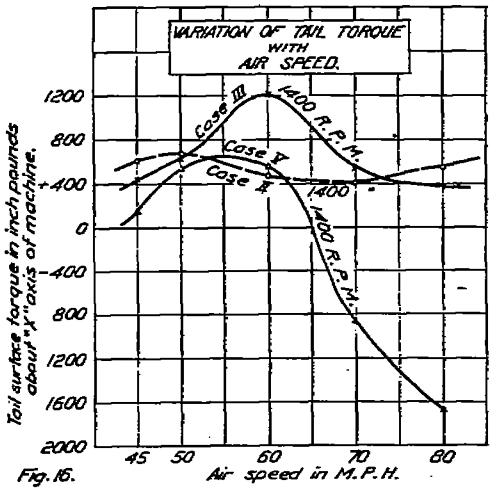


Fig. 16.

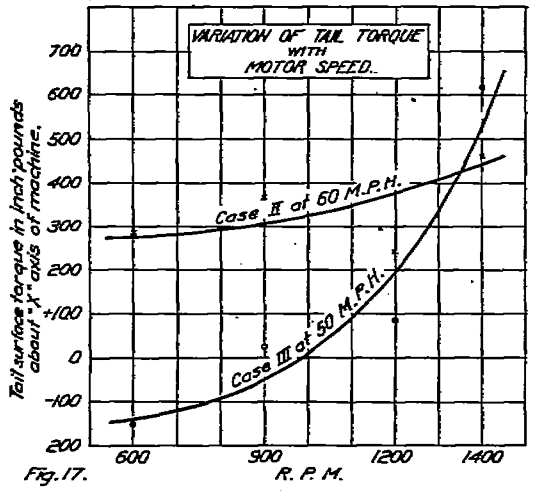


Fig. 17.

TORSIONAL EFFECT DUE TO THE UNSYMMETRICAL LOADING OF THE TAIL PLANE.

DISTRIBUTION OF LOAD ALONG THE SPAN OF THE TAIL SURFACE.

In figures 243 to 264 a few cases have been worked out showing the total pressure on the tail taken normal to the X-axis of the airplane. These curves, while they show the shape of the pressure variation quite accurately, should not be taken as an indication of the exact total pressure, as it is impossible to fair these curves exactly, due to the irregular position of the holes; and for this reason they do not check with the more accurate determination obtained from cross fairing. They do show, however, the concentration of the load on the tip of the tail plane and also the unsymmetrical loading due to the rotation of the slip stream.

All of the curves show a double maximum at the tip, the edge of the slip stream causing the inner one and the raked tips the outer. Although no torque curves were drawn for Case VI, it is very evident from an examination of the pressure curves that the torque on this tail is very small. This can be explained by the fact that the tips of the tail plane are out of the slip stream, so that there is little inducement for the building up of high pressures at these points.

VARIATION OF TORQUE WITH AIR SPEED.

In figure 16 are shown three curves representing the torque in inch-pounds about the X-axis of the airplane plotted against air speed in miles per hour for several cases, at 1,400 revolutions per minute. All of the curves increase to a positive value of the torque from 45 miles per hour to about 60. From that part on, however, the curves fall off quite rapidly, especially in Run V where the curves indicate a considerable negative value. The shape of these curves is rather peculiar and it would not be expected that a maximum of positive torque would be reached at a speed of 60 miles an hour. An explanation may be obtained perhaps by studying the velocity diagram obtained by the Royal Aircraft Establishment on a BE2C airplane of the tractor type.[3] These results show that the slip-stream is divided by the wings and body into two separate streams, one with an inclination downward and the other with an inclination upward, and that these two streams are in various positions according to the slip of the propeller. It would be expected that the rotation of the slip stream would be proportional to the slip of the propeller; that is, at low air speeds and high engine speeds that the rotation of the slip stream would be a maximum and at high air speeds and low revolutions per minute that the slip stream might even rotate in the direction opposite to that of the propeller. Therefore, with a constant engine speed the positive torque on an airplane should be greatest at the low speeds and should increase proportionally to the air speed. The results of the British, however, as above referred to, show that the regions of high velocity do not occur at the same place at all flying conditions, but that the high-velocity regions are rotated with the propeller as the slip increases. This effect may then cause the high-velocity region of the slip stream on one side to flow either above or below the tail plane in some flying conditions, so that the torque would be in that case greatly changed as the slip stream on one side would strike that half of the tail plane and the slip stream on the other side would come above or below

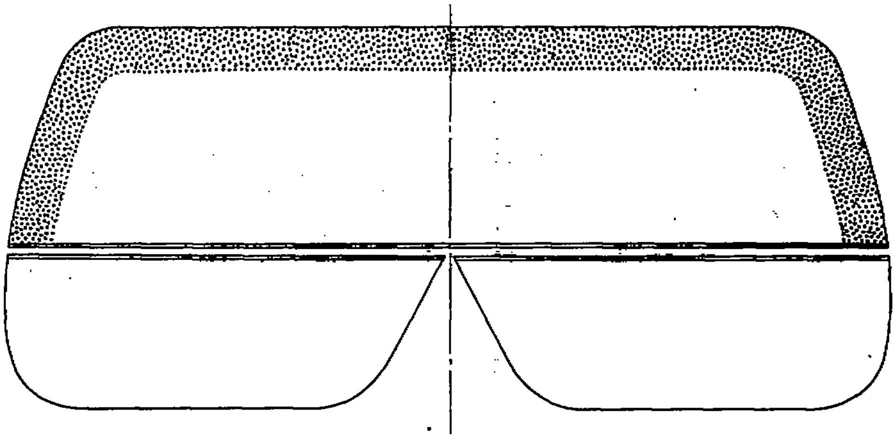


Fig. 18. METHOD OF DISTRIBUTING LOAD IN A SAND TEST.

it, thus making a large difference in the pressures on the two sides of the tail plane. That is, one-half of the tail, although it may have the higher angle of attack, due to slip stream rotation, at the same time it can have the lower load because of the greatly lowered slip-stream velocity on that side. This is undoubtedly the cause of the large negative torque that occurs on Run V at high air speeds.

VARIATION OF TORQUE WITH ENGINE SPEED.

In figure 17 are plotted curves showing the variation in tail-plane torques with a change in engine speed. These curves show, as would be expected, that the torques take a more positive value as the revolutions per minute of the engine is increased. A cause that may change the pressure distribution on the tail plane somewhat, and one that can not well be eliminated, is the effect of the rudder, as this member must be set over more to the right as the rate of engine speed is increased, in order to balance the torque of the propeller.

RECOMMENDATIONS FOR SAND LOADING TAIL SURFACES.

It is, of course, impossible to draw a final conclusion on the most logical method of sand loading until the work on tail loads in accelerated flight has been completed; however, as the tail load is usually considered to be of considerable magnitude in a rapid nose dive, the general characteristics of the regions of highest pressure may be summarized as follows:

[3] The Design of Screw Propellers for Aircraft, H. C. Watts, pp. 180-182.

(1) The most highly loaded region lies along the leading edge and along the tips of the tail plane and is of very narrow width, being about one-fifth of the chord of the whole tail surface, with the exception of Case V—where the tail plane was inverted—in which case the distribution was over the first three-fifths of the tail surface.

(2) The load on the tail (negative) is proportional to the position of the center of gravity; that is, the further forward the center of gravity the greater is the load on the tail.

(3) The distribution of load along the span of the tail plane shows regions of high pressure at the tips.

(4) In some cases, particularly at high engine speeds, there may be a large up pressure on one half of the tail plane and a large down pressure on the other half.

(5) The down load on the elevator is in all cases very small and at times the up load may be considerable, but the latter is balanced by the static weight of the elevator and so is relatively unimportant.

It should be noticed that the preceding conclusions are based only on uniform flight, with speeds up to 100 miles per hour, and the distribution, especially the down load on the elevator, may be considerably altered when this member is moved to a large angle with the tail plane, as would occur in accelerated flight. It is probable, however, that the load on the tail plane

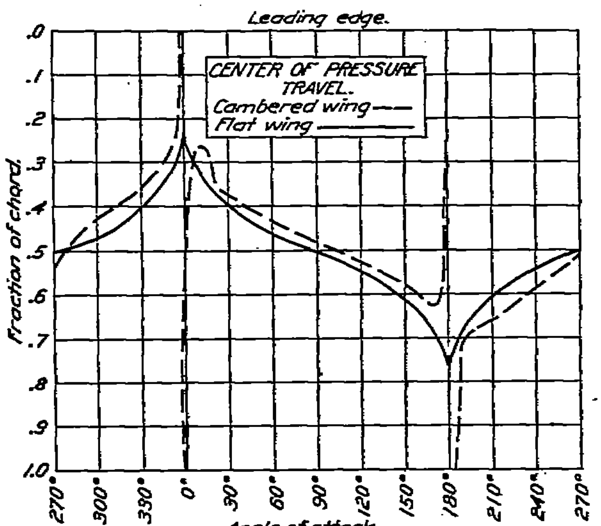


Fig. 19.

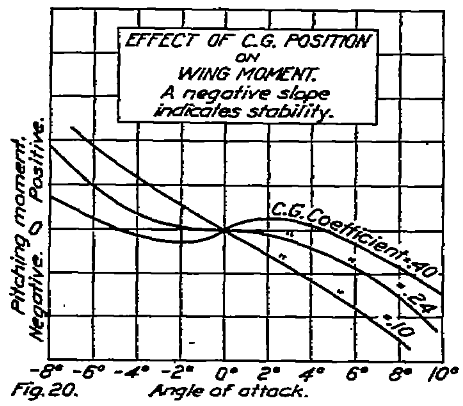


Fig. 20.

will not be much increased in stunting, as the damping effect will somewhat neutralize the load. The following recommendations for sand loading the tail surface are based on the conslusions from these tests in uniform flight:

1. A unit loading on the tail surface of 3 pounds per square foot with a center of gravity position of 0.30 will be sufficient for speeds up to 120 miles per hour. Of course, this unit loading should be multiplied by the load factor which is used on the remainder of the airplane.

2. The unit tail loading of the airplane should vary with the position of the center of gravity and it is recommended that if a center of gravity coefficient of 0.30 is taken as unity, 5 per cent of the tail load should be subtracted for every per cent that the center of gravity is back of this point (the center of gravity coefficient not to exceed 0.40), and 10 per cent should be added to the tail load for every per cent the center of gravity is forward of this point, percentage being taken on the mean wing chord.

3. The load should be distributed on the tail in a sand test around the leading edge and at the tips with a width of about one-fifth of the total tail surface chord as shown in figure 18.

4. Because of the unsymmetrical loading of the tail surface at times, one side of the tail surfaces should be loaded at a time; that is, one half should be completely loaded, the load removed, the second half completely loaded and then both halves loaded together.

5. In uniform flight the elevator load can be neglected, as the loads are upward and these are balanced in a large part by the static weight of the elevators. The elevators should have a separate test in order to withstand a pull on the control stick which will represent the maximum that it would be possible for the pilot to exert, but this load would occur only when suddenly pulling up the elevators and would not be present in uniform flight.

LONGITUDINAL STABILITY.

The subject of longitudinal stability in free flight is in a rather confused state because of the complex effects of the slip stream, which are not as yet thoroughly understood. Practically all of the stability theory is based on coefficients which are determined from model tests made in the wind tunnel, and up to the present time it has been impossible to reproduce accurately the slip stream in the wind tunnel; so that the tests made in this way are not in any way comparable with conditions in free flight when the engine is running. Only by a study of the forces on the controls and an exploration of the velocity and angle of the slip stream during various flight conditions can we come to any conclusions as to the effects on the longitudinal stability of various alterations in the airplane. It has been shown that the two causes which have the greatest effect on the longitudinal stability are the position of the center of gravity and the size, form, and position of the tail plane.

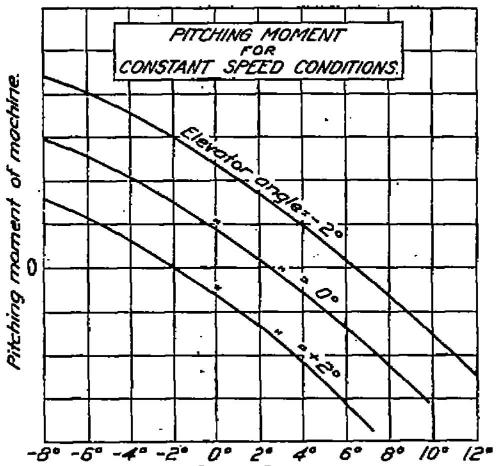


Fig. 21.

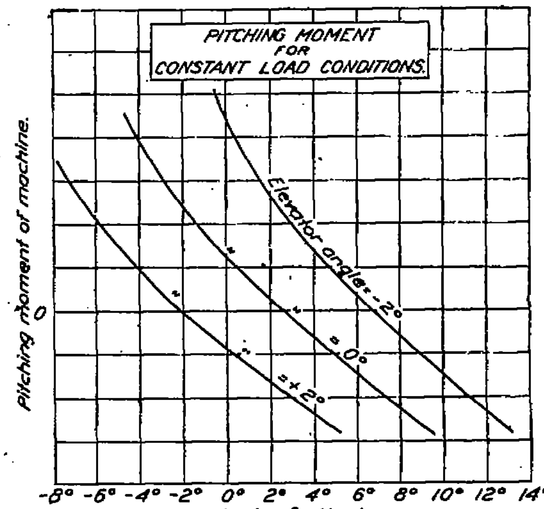


Fig. 22.

THE FUNCTION OF THE HORIZONTAL TAIL SURFACES.

The methods of obtaining longitudinal stability by means of a horizontal tail surface can be made clear by citing a few simple examples. There is, in figure 19, plotted the center of pressure travel for a flat plate and a typical aerofoil. If the flat plate is supported at its leading edge or ahead of its leading edge it will evidently be stable—in the manner of a weather vane—for any angle of incidence, although there will be a position of unstable equilibrium at 180°. If the support is now moved 0.3 of the chord back from the leading edge, the plate will be stable at an angle of +70 (where the center of pressure is at the support), and is in unstable equilibrium at 0°. This is the case of a balanced control surface which has a small unstable range about the zero position, a rather undesirable condition, especially on airships. Therefore a flat plate or a thin symmetrical surface must be supported at least as far forward as the leading edge to obtain complete stability when moving at a constant velocity.

Now, considering the stability of a cambered surface, which has an unstable center of pressure travel, it can be shown that if the air passes by the wing at constant speed we may still have stability by placing the support far enough forward. For this purpose moment curves are plotted in figure 20 for various positions of the support, and it is seen that the wing is completely stable—a curve of negative slope—when it is supported less than 0.24 of the chord from the leading edge. It should be noted that the support need not be taken as far forward in the case of cambered wing as with a flat plate in order to get stability even though the latter has a stable center of pressure travel. It may be concluded that a surface run at constant speed may be made stable, no matter what the center of pressure travel, provided the support be taken sufficiently far forward.

For the full-sized airplane, however, we have different conditions; that is, there is a constant weight on the airplane and the speed varies in uniform flight in such a way that this weight will just be supported. Also in uniform flight the moment about the center of gravity must always be zero; that is, the moment due to the wings and body must at all times be balanced by a moment, in the opposite direction and of the same magnitude, exerted by the tail surfaces. In the case of an airplane in flight, then, the moment curve will be defined by the weight of the airplane multiplied by the distance of the center of pressure to the center of gravity. This curve will, therefore, always have the same shape no matter what the position of the center of gravity, thus giving the moment curves of the wings stability or instability according to whether the center of pressure travel is stable or unstable.

As it is impossible to make a simple surface stable at varying speeds unless the center of pressure travel is stable and there is no practical surface with this property, it is necessary to resort to a secondary surface known as the tail plane to obtain stability in a full-sized airplane. The tail plane acts in the same way as the vane on a weathercock; that is, the moment curve due to the tail is very stable because of the large distance between the tail plane and the center of gravity. In this case the tail plane does not carry a constant load, as do the wings, so that its moment curve can be very stable even though the center of pressure travel for the surface itself be unstable. Suppose a series of moment curves are plotted as in figure 21 for a model airplane in the wind tunnel at various positions of the elevator. Now, if this airplane is flying at varying speed and constant load, the moments on the model tests at any given angle of incidence would be multiplied by the square of the ratio of the corresponding full-scale speed to the speed of the model test, giving the series of curves shown in figure 22. It is seen that these new moment curves are stable at high angles of incidence and are all tangent to the constant moment curve at zero moment; but as the moment of the full scale airplane at a constant flight speed must be zero, the only part of the variable-speed curve we are interested in is where it crosses the zero moment axis. The stability is determined by the slope of the moment curve, and as the two curves—constant and varying speed—are tangent at zero moment, it is evident that the stability at varying speed is the same as at constant speed, providing the moment curves for various elevator settings are parallel; and this is the case in practically all airplanes. From the standpoint of efficiency it is not desirable to move the center of gravity far enough forward to obtain complete stability for the wings alone, but this is unnecessary if the moment curve of the tail is stable, for by combining a very stable tail with a slightly unstable wing the complete airplane will have stability.

The moments of unstable wings can be made stable at constant speed by moving the center of gravity far enough forward, but with a constant load and varying speeds, the stability of the wings can not be changed by varying the position of the center of gravity. The complete airplane, however, has the same stability for varying speeds as it has for constant speed. It should be noticed that although the vectors obtained by a model test may be stable, this does not mean that an airplane in free flight will be stable; on the other hand, an airplane may be stable in flight even though it has an unstable position of the vectors. However, if the slope of the moment curve on the model is negative the full-sized airplane will be stable, and if positive it will be unstable, of course neglecting the effect of the slip stream.

ACTION OF THE TAIL PLANE AND ELEVATOR IN PRODUCING PITCHING MOMENTS.

The horizontal tail surface consists, in almost all modern airplanes, of a fixed portion with a movable portion hinged to its rear edge. The turning of the rear part will, first, change the angle of attack of the entire tail surface, and, second, change the camber of the section, thus effectively changing the lift coefficient of the tail by the application of very little force to the controls. The pressure curves indicate that the distribution of load is constant between the two parts of the tail for the small angular changes used in flight, so that it may be assumed that the force on the elevator is very nearly proportional to the force on the whole horizontal tail surface. This is confirmed by the similarity between the stick force curves and the pitching moment curves of the tail, although there is a discrepancy at very low speeds where the elevator angle is quite large.

It is desirable in every airplane to have the stick force zero at the normal flying speed, a result that may be accomplished in two ways; first, the inevitable weight of the elevator may be balanced statically by weights or springs, or, second, the weight may be balanced—as is usual—by the air force acting on that member. Now, in order to obtain a sufficient air force to balance

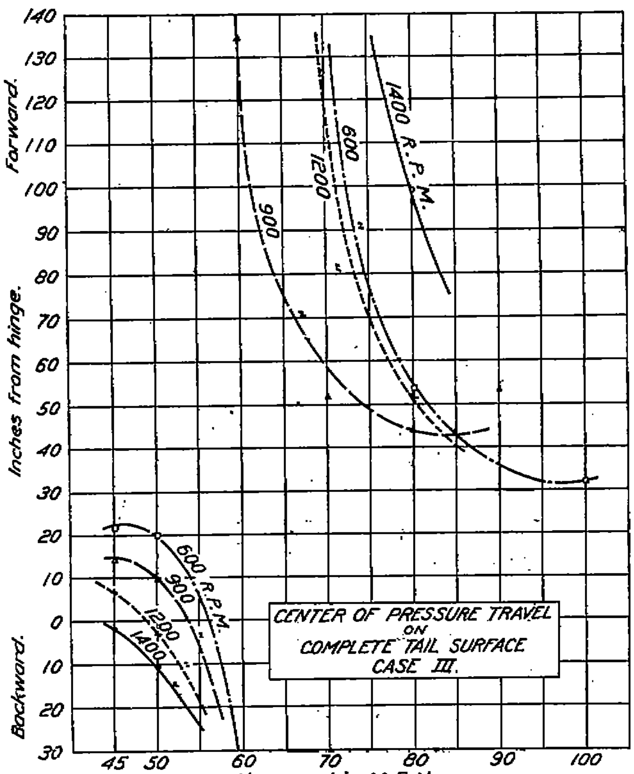


Fig. 23.

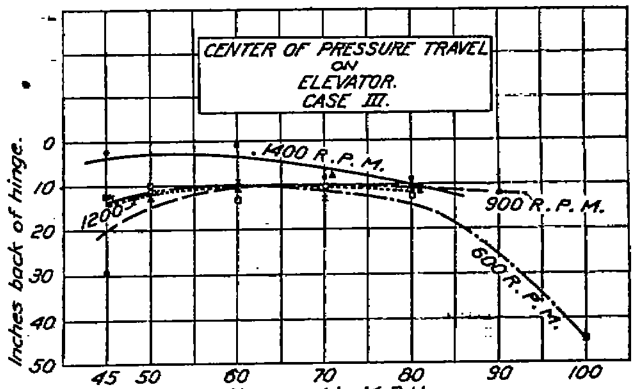


Fig. 24.

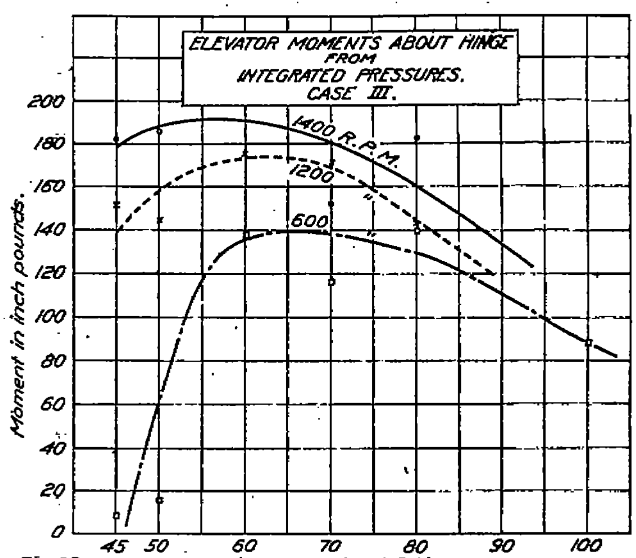


Fig. 25.

the weight of an ordinary elevator, it is necessary to make a change (backward) of the center of gravity to increase the total up load on the tail, of which the elevator will get a small share; or, better, to decrease the angular setting of the tail plane, which, as has been shown, increases the proportion of load on this part. This is the function of the adjustable tail plane which can be used to minimize the stick force at any ordinary flight condition. Even a small change in elevator weight may greatly alter the stability of the airplane because of the important changes that are made on the airplane to balance it aerodynamically. As will be shown later, these changes greatly affect the distribution of pressure on the tail surface.

The tail surface works normally at rather small angles of incidence and with a small total load; so that the center of pressure is often off of the surface, thus having little significance. The load on the tail generally reverses in sign at a certain speed making the center of pressure curve discontinuous. The center of pressure curves for Case III are plotted in figure 23 against air speed; a separate curve for each engine speed. The curves are quite regular and the vectors are further forward with the lower engine speeds. At 65 miles per hour, where the load changes sign, the vector passes off the rear and returns at the forward edge of the tail plane.

The center of pressure curves for the elevator alone are shown in figure 24; the curves for the various engine speeds being close together, with a tendency for the center of pressure to be further forward with higher engine speeds. The movement of the center of pressure is small, and moves forward from 45 miles per hour to 60 miles per hour, but at higher speeds again moves to the rear.

In figure 25 are plotted the moment curves of the elevator about its hinge for various engine speeds and air speeds, and while it is evident that a great many of the points do not lie on the curve, because a very small error in drawing the pressure curve at the trailing edge of the elevator makes a great difference in the moment about the hinge, these curves can be considered as fairly accurate, as they check with the moment curve obtained by measuring the direct force on the control stick, and it may be considered that they are sufficiently correct for an illustration. With a center of gravity position in this run—a coefficient of 0.324—it is shown that the moments are all positive; that is, there is a tendency of the air to lift the elevator. At low air speeds this upward force on the elevator is rather small, especially at low engine speeds; but as the air speed is increased the load reaches a maximum at about 65 miles an hour. As the speed increases from this value the curves all tend to go downward; that is, the upward force on the elevator is increased about proportionally to the air speed. In order to complete the data, in figure 26 are plotted curves showing the angles of the elevator for a similar condition of flight, and it is interesting to notice from these curves the small angle the elevator moves through for greatly changing flight conditions, and for this reason it is unnecessary in this report to resolve any of the forces on the elevator into the plane of the tail plane. These curves show that the angle of the elevator is increased; that is, is more positive as the air speed increases up to about 55 miles per hour; from this point on, however, the angle of the elevator slightly decreases and reaches about a neutral angle at the higher flight speed. It also shows that the higher engine speed requires the greater positive angle of elevator setting.

ACTUAL PITCHING MOMENT ABOUT THE CENTER OF GRAVITY DUE TO THE TAIL PLANE.

The pitching moment produced by the tail plane about the center of gravity of the airplane is evidently found by the product of the distance from the center of pressure of the horizontal tail surfaces to the center of gravity and the load on the tail as found by integrating the pressure over the whole of the horizontal surface. In figures 27 to 31 the curves as determined in this way are plotted against the air speed in miles per hour for various engine speeds. As shown in the curves for Case I, the pitching moment has a more positive value as the engine speed is decreased, except at 600 revolutions per minute, which is in nearly all the other cases abnormally high. The curves all decrease from a negative to a more positive value as the air speed is increased, and within the experimental error the curves are parallel; at low speeds the curves become more nearly horizontal. It will be noted that in Case I, where the center of gravity was a large distance back on the mean chord, that the curves for different engine speeds are quite widely separated, while in Cases II, III, and IV the curves lie very closely together; but in Case V the curves are again separated at high speeds, and it is a remarkable fact that the order of the curves in this case is entirely reversed; that is, that the curve at 1,400 revolutions per minute is lowest and that at 600 revolutions per minute is highest. As the thrust line of the engine is about 3 inches below the center of gravity of the airplane, it would be expected that at high engine speeds the thrust would tend to produce a positive moment on the airplane and that this would be resisted by a pitching or negative moment on the tail plane, and this is evidently what happened in most of the cases. The reason for the abnormally high negative value of the pitching moment curve for 600 revolutions per minute is not very clear, and it is probably due to some effect of the slip stream—or lack of slip stream—on the wings or body. The complete reversal of the moment curves for Case V, however, is still more puzzling and can only be explained by the change in stagger—which was necessary in this case—producing different forces by interaction with the slip stream. As would be expected, the pitching moment

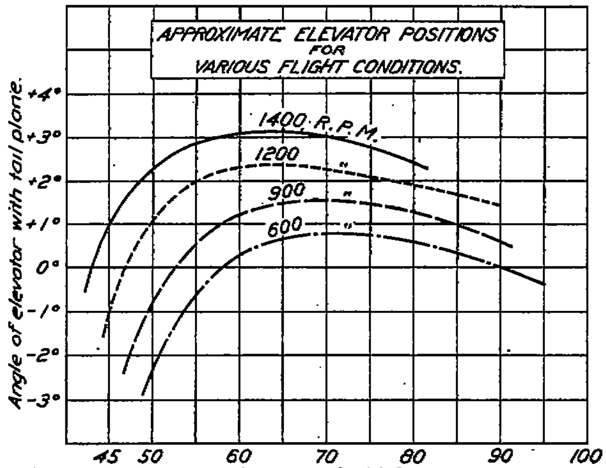


Fig.26.

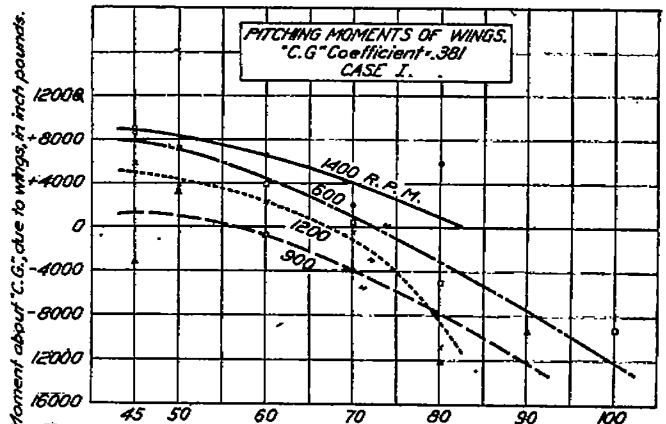


Fig.27.

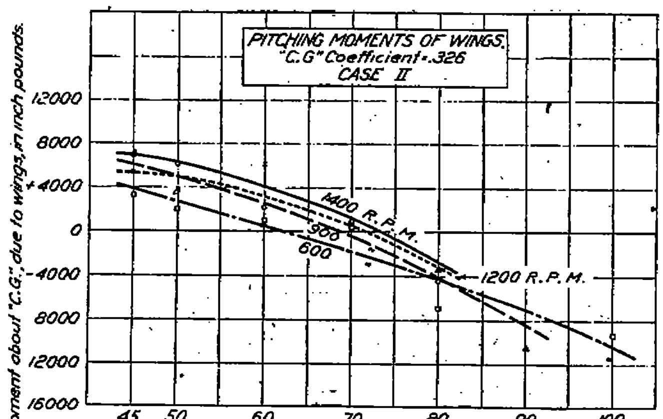


Fig.28.

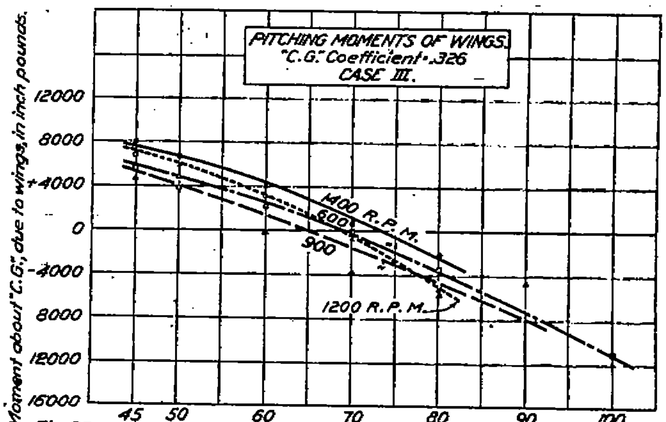


Fig.29.

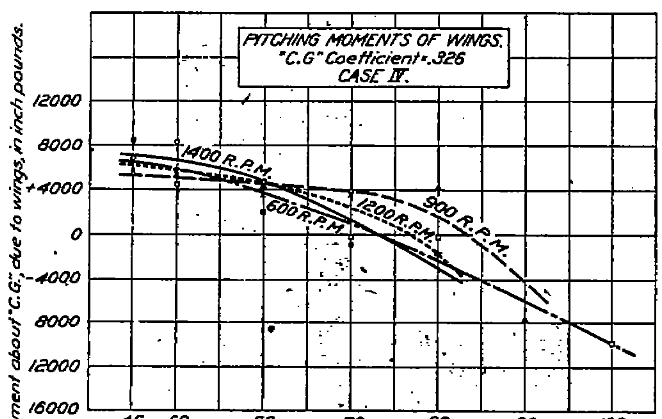


Fig.30.

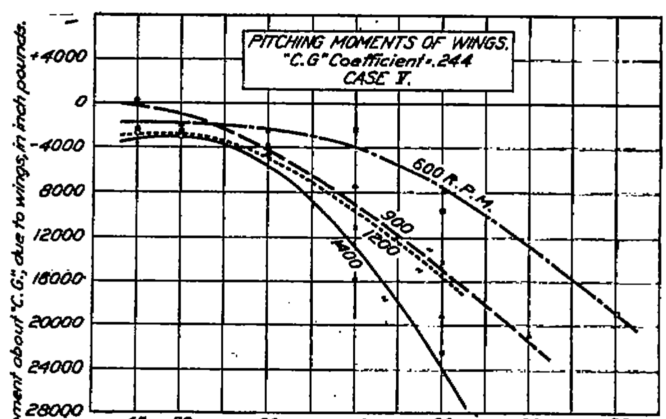


Fig.31.

curves have a more negative value as the center of gravity is moved forward, and, as will be shown later on, the center of pressure curves from these moments show very good agreement for all center of gravity positions.

CENTER OF PRESSURE TRAVEL COMPUTED FROM MOMENT CURVES.

The distance of the center of pressure from the center of gravity of the airplane is evidently equal to the moment about the center of gravity due to the wings, divided by the weight of the airplane, which is constant; so that in all cases the center of pressure curve will be parallel to the moment curve no matter what position the center of gravity has. In figure 32 is shown the center of pressure curves for all cases and also for the case of a wing tested in the wind tunnel having the same section as that of the full-sized wing. In order to obtain the true pitching moment of the wings alone, the moment of the chassis and body, although small, must be subtracted; so a model body and chassis were tested in the wind tunnel in order to obtain their true pitching moment about the center of gravity in each case (fig. 33). These values, corrected for scale, were then subtracted from the full-scale pitching moment due to the tail, thus giving the moment for the wings alone. It will be seen that the results of the several cases check very closely, and it may be concluded that this center of pressure travel is very close to that actually occurring in flight. The full-flight center of pressure travel is, however, considerably farther forward than it is in the model, and this is the same conclusion that was

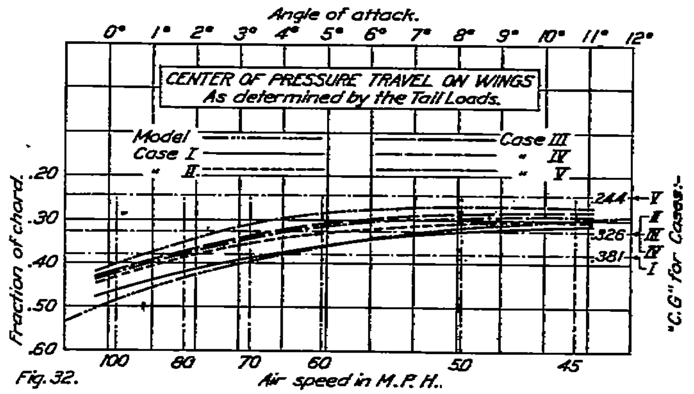


Fig. 32.

reached by the British in their tests as noted previously. The difference is not great, but still it is enough to account for a considerable lack of balance in the full-size airplane if the center of gravity position is computed strictly from wind-tunnel results. The total travel of the center pressure on the full-sized airplane is less than it is on the model; so that the full-sized airplane might be expected to be more stable than the model under similar conditions.

THE RELATION OF THE STABILITY TO THE PRESSURE DISTRIBUTION ON THE TAIL SURFACES.

The stability of the airplane is dependent upon two factors; the first is the moment curve of the wings alone, which in most cases is unstable, and the second the moment curve of the tail, which is usually very stable. The first is mainly affected by the wing section used, by the amount of stagger, and, most important, by the position of the center of gravity; the second is affected almost entirely by the length of the body and by the aspect ratio of the tail plane, for the moment curve will evidently be more stable the more rapidly the lift of the tail plane is changed for a given change in the angle of attack, and this change in slope of the lift curve is mainly affected by the aspect ratio of this surface. The stability of the airplane, then, can be increased in two ways; first, by making the moment curve of the wings more stable, or, second, by increasing the efficiency of the tail surface.

The stability of an airplane, as shown in Report No. 96, may be measured in two different ways; one with fixed controls and the other with free controls, and, as is generally the case, the stability with fixed control evidently depends on the change in the position of the elevator for different flight conditions, while the stability with free controls depends entirely on the force on the elevator for various flight conditions. It is this last condition which can be studied quite readily from the distribution of pressure on the tail surfaces, and in no other way can the exact process of the stabilizing effect on the tail plane be visualized.

In order to study more clearly the effect on the pressure distribution on the horizontal tail surfaces of various changes in the airplane, the pressure distribution curves are shown in figure 34 for the different cases at 600 revolutions per minute and at the various air speeds investigated. These curves are not drawn as accurately as the originals and are only intended to bring together in one place the various curves, so that they may be more easily compared; but their accuracy is quite sufficient for use as an illustration.

In Case I there is a marked upward pressure at the leading edge of the tail plane at the lowest speeds, but as the speed increases this region of upward pressure moves backward, and at about 60 miles per hour a region of downward pressure appears at the lower side, increasing to larger and larger values as the speed increases. It will be noticed that as the air speed drops from 60 to 50 miles per hour the upload on the elevator increases (unstable), due to increased suction near the hinge. From 50 to 45 miles per hour the upload increases (stable), due to the elimination of the downward pressure at the trailing edge of the elevator caused by its more negative

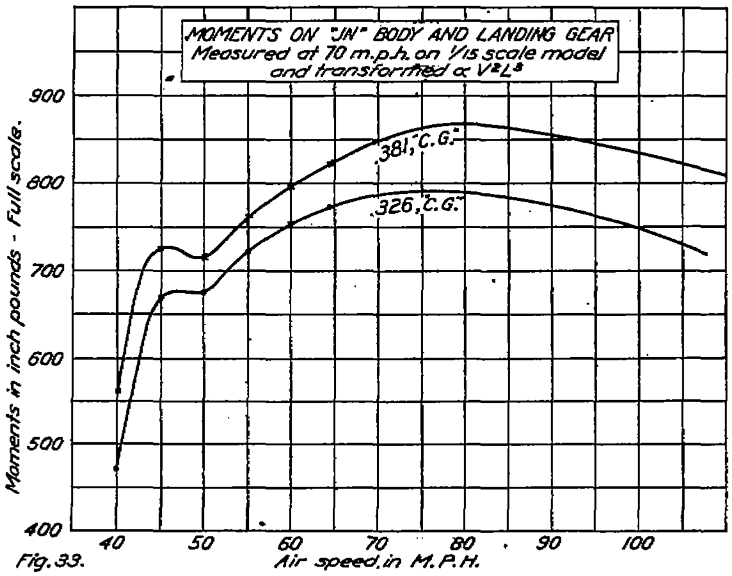


Fig. 33.

angle. On the other hand, as the speed increases from 60 to 100 miles per hour the upload is decreased (unstable) until at the highest speed the load becomes downward, due to a negative pressure region at the rear of the elevator caused by the positive elevator angle. At the high speed not only the weight of the elevator itself but the downward air force must be held by the pilot, making it necessary for him to exert a considerable pull on the control stick; and if the control in this position were released the airplane would immediately nose over onto its back, a thing which has actually happened with this type of airplane in actual flight.

It might be well to define here the terms "tail heavy" and "nose heavy" as used by the pilot. Generally speaking, the pilot considers an airplane nose heavy when there is for the greater portion of the flying range a pull on the stick; inversely, it is tail heavy if there is an undue push on the stick. This force on the stick may be due, however, to two causes: The first is the weight of the elevator itself, which is no unimportant part of total stick pull, and the second is the air load on the elevator, which, it will be seen, varies with the different flight conditions. For a balanced condition of the control it is necessary, then, to have an upward air force on the elevator which is equivalent to the weight of that member, and in some instances the elevator is so heavy that this necessitates a large and usually detrimental change in the airplane to affect this condition.

In Case II the only change that has been made from the preceding is the movement of the center of gravity from a coefficient of 0.326 to 0.381. It will be seen that there is no great change in the distribution of pressure; a general increase on the upload of the tail surface is all that is seen, as would be expected from a change in the center of gravity. The general characteristics of the pressure on the elevator are the same as before, except that the load on the elevator is more downward at low speeds and of about the same value at high speeds, so that the airplane is on the whole more nose heavy; still the stability has been improved, this improvement being due primarily, of course, to the more stable moment curve of the wings, and the tail load is balanced by this moment.

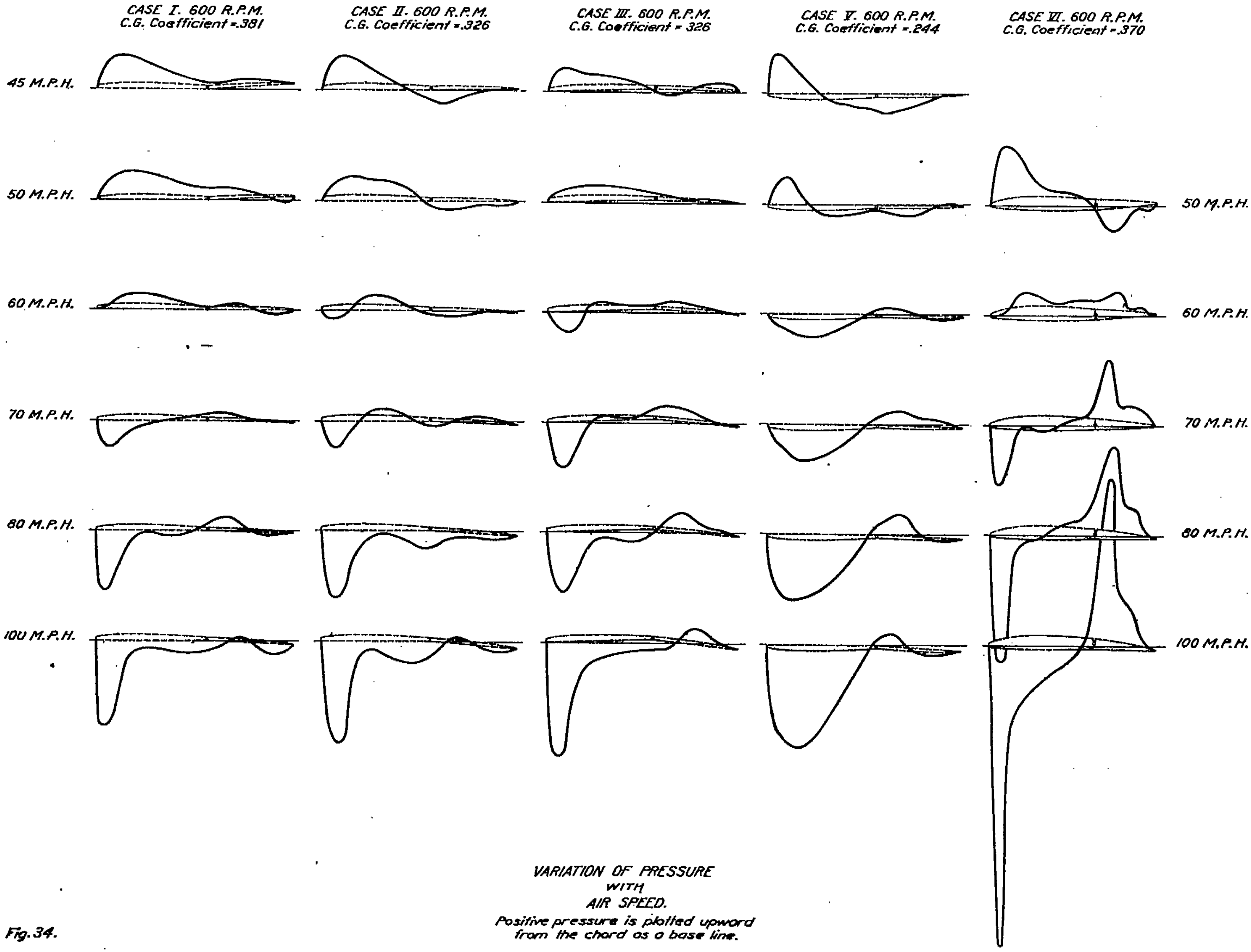
In Case III the only change was the more negative setting of the tail plane; the pressure distribution, however, suffers a considerable alteration. In the first place, there is at the leading edge a small region of upward pressure at low speeds and a greater region at low speeds than occurred in the preceding case, and, as was shown before, the distribution of pressure between the tail plane and elevator is such as to increase the positive load on the elevator and decrease that on the tail plane. The elevator has a considerable upload in all cases due to the elimination of the negative pressure area at its trailing edge, and this is confirmed by the decreased nose heaviness in flight. The function of the adjustable tail plane, therefore, is not to alter the total load on the tail plane, as this must be constant for any one flight speed and center of gravity position, but to vary the distribution of load between the movable and fixed portion of the tail surface, so that the moment about the elevator hinge may be made as small as desired. It is evident by the pressure distribution curve that the stability is increased by a negative change in the stabilizing angle; that is, there is less down load on the elevator at the higher flying speeds.

In Case V where the tail plane is inverted—that is, the flat surface uppermost—a very considerable change in the pressure distribution is shown. The negative region at the leading edge at low speeds is concentrated more nearly at the front, but at higher speeds the pressure reverses and the positive region is more to the rear; so that the region of maximum pressure is moved a considerable distance back on the tail plane, and altogether there is a greater load on the tail plane than in any other case, as would be expected with a more forward position of center of gravity. The pressure conditions on the elevator are quite different in this case, due chiefly to the very forward position of the center of gravity, but undoubtedly the more efficient action of the tail plane in this position increases the high speed stability as shown in Report No. 96. There is a down load on the elevator at low speeds which changes to an up load as the speed increases, producing considerable stability, although the airplane is at all times rather nose heavy.

In Case VI the center of gravity coefficient was 0.370 and the special tail plane was used having a greater span and a thicker section. The distribution of pressure over the tail plane is very different from the other cases, and while the pressure curves for similar conditions have somewhat the same shape, the down pressure at the nose and the up pressure at the tail were very much exaggerated, producing exceedingly large values at high speed; and these higher pressure regions are concentrated on a very small portion of the chord in each case. It is also evident from the curves how great is the stability of the airplane with this tail plane even though the center of gravity is far back—as the downward pressure on the elevator at low speeds rapidly increases with the air speed to rather great upward values.

THE EFFECT OF THE SLIP STREAM ON STABILITY.

It has been clearly shown in Report No. 96 that the longitudinal stability of the tail plane is considerably decreased by the effect of the slip stream on the tail surface, because if these members are in constant or nearly constant flow of air it is much more difficult to obtain stability than if they are in an air flow which varies as the speed of flight. The efficiency of the tail surface then will be proportional to the amount of area which is outside of the slip stream, so that a tail plane of high aspect ratio is of great advantage in increasing the stability, not only because it increases the steepness of the lift curve but because it has a considerable amount of area which is outside of the slip stream.



VARIATION OF PRESSURE
WITH
AIR SPEED.

Positive pressure is plotted upward from the chord as a base line.

Fig. 34.

The effect on the stability of an airplane from the variation in the slip stream caused by changing the engine speed is very complex and little actual data have been obtained on it. For the purpose of showing more clearly the effect on the pressure distribution over the tail surfaces with the variation in engine speeds, there are shown in figure 35 the various curves of pressure distribution for the four engine speeds tried, and for the various conditions of the airplane. As in figure 34, these curves are not intended to represent accurately the pressures, but are only drawn in a general way to serve as an illustration; Case IV was omitted for the reason that it showed no difference from Case III, and in Case VI there were no runs taken at 900 and 1,200 revolutions per minute.

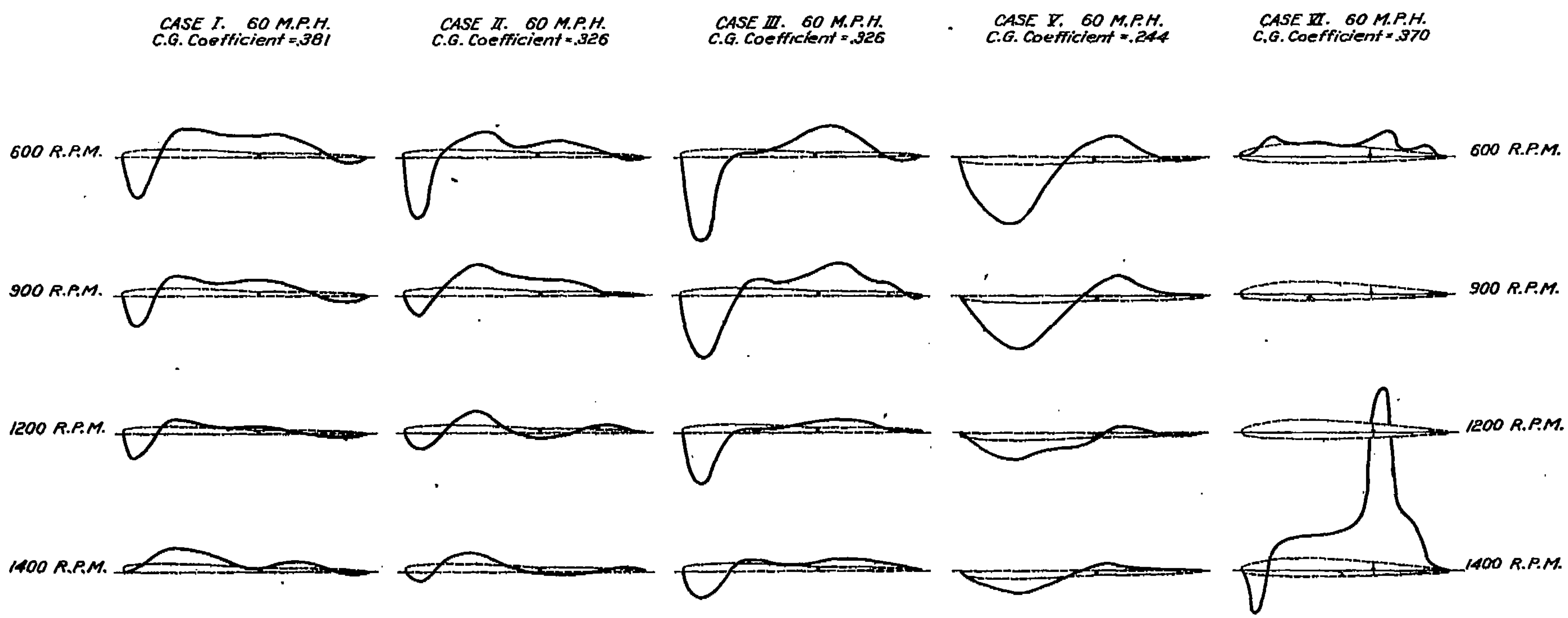
The free control stability as determined for this airplane in Report No. 96 shows that in general there is a pull on the stick, and the down load on the elevator is greatest at low engine speeds. This effect is shown in all the cases, although it is not as evident visually as might be expected because the downward pressure at the low engine speeds occurs at the trailing edge of the elevator, and even though the total load on the elevator does not decrease with the air speed, the moment about the hinge will be more negative with the lower air speeds. In all cases the lower engine speed produces a greater down load at the nose of the tail plane and at the same time a higher region over the hinge, and as the engine speed decreases there is a greater region of down pressure at the rear of the elevator.

How far the effect of the slip stream changes the distribution of pressure over the tail surfaces by a change in velocity or by a change in direction can not be determined until more complete data are obtained on the slip-stream direction and velocity around the tail surfaces. It is necessary, however, to distinguish between cause and effect; that is, there is a pitching moment about the center of gravity due to the wings, the body, and the moment of the propeller thrust about the center of gravity; all of which must be balanced by the load on the tail, and in steady flight the elevator must be placed in such a position that this load produces a moment about the center of gravity which is exactly equal to the total moment produced from the other causes. Therefore, the change in total load on the tail surfaces at a given air speed must be due to a change in moment about the center of gravity, caused either by the moment of the propeller thrust about the center of gravity or by the slip-stream effect on the wings and body; on the other hand, the distribution of pressure over the tail surfaces and the change in pressure on the elevator in particular are determined by the direction and velocity of the air passing over these surfaces, and this changes (at constant flight speed) only with a variation in the speed of the engine. With a constant setting of the elevator in an airplane which is flying, trimmed at, say, 600 revolutions per minute, when the engine is opened up to 1,400 revolutions per minute the average airplane will tend to climb. This is due not primarily to the fact that the thrust line is slightly below the center of gravity but is mainly due to the fact that the velocity over the tail is greater and in a more downward direction—that is, the negative load on the tail is greater—which tends to raise the nose of the airplane to such an angle that the moment of the tail plane is balanced by the moment of the wings about the center of gravity; therefore, the more stable the airplane the less variation in air speed will there be between various throttle settings for equilibrium conditions.

SUGGESTIONS FOR FURTHER RESEARCH.

As the value of a research is not only in answering questions but also in finding questions to answer, it is believed that a short discussion of the difficulties encountered in this investigation and the problems for which a satisfactory solution has not been arrived at will be of value in guiding future work of this kind. It might be argued that unsolved problems would be of little value to the average person, but the recognition of problems that are worth solving is a step ahead in any branch of research and their suggestion may lead to new lines of thought.

One of the most important problems, and one on which there has been only a little light shed, is the section of the tail plane. It is seen from the tests in this report that the tail plane with a thick section gives very high local pressures at the leading edge and at the elevator hinge, but at the same time it also gives to the airplane an excellent degree of stability; and the ques-



VARIATION OF PRESSURE
WITH
MOTOR SPEED.
Positive pressure is plotted upward
from the chord as a base line.

Fig. 35.

tion that has not been answered is whether the even distribution of pressure over the tail surfaces is incompatible with a stable tail moment curve. It is suggested in Report No. 96 that the point of maximum stability depended upon the relation of the camber on the upper or lower surface of the tail plane, and that a high upper camber gives stability at low speeds, while a high lower camber gives stability at high speeds. Also the results in this report show conclusively that a tail plane with a flat upper surface and a considerable camber below gives a much more even distribution of pressure than the usual type of tail where the flat surface is the lower. The whole problem, then, consists in finding that section which will give the greatest stability with the most even distribution of load over the tail surface. Of course in some airplanes a high degree of stability is not required or even desirable, in which case it is still best to use the most efficient tail section, and if the stability is to be reduced, to cut down the area of the surfaces.

Another unsolved problem which is of the greatest importance in the design of tail surfaces is the investigation of the causes for the vibrations which occur in some tail planes. It is believed that this is the reason for the failure of some tail planes which are structurally quite strong enough to withstand the static load which is imposed upon them. The data from this investigation show that there is in some instances a very great torsional load on the tail plane about the Y-axis which produces a considerable change in the angle of setting of this member due to deflection, and this deflection in turn would cause a still greater change in the pitching moment; so it is quite conceivable that pressure conditions could arise in which an oscillation would be set up about the Y-axis which might become dangerously large for certain speeds.

In regard to the changes in the methods and instruments which would be recommended for another test of this kind, the first would be the recording on the same film with the pressures, as at present, the value of the air speed, the engine speed, and the angle of the elevator. This could be done very easily by measuring the air speed by the height of the liquid in one of the tubes in the same way that the pressures are measured, and the revolutions of the engine could be recorded in the same way with a liquid column raised by a centrifugal pump as in the Veeder liquid tachometer. The angle of the elevator could be easily recorded by placing a scale in the center of the gauge and having a small pointer running over it on a flexible wire connected to the control system. In this way a better check could be obtained upon the accuracy of flying done by the pilot, and it would also give additional data which would be of value in studying the results of the pressure readings. As mentioned before, the necessity for making capillary corrections for each one of these tubes in the gauge was very laborious, and in another instrument every effort would be made to obtain tubes of such uniform bore that these corrections could be neglected.

CONCLUSIONS.

STRUCTURAL CONSIDERATIONS.

The most interesting results obtained from these tests are, perhaps, the very low average load per square foot on the usual type of tail plane during steady flight; so small in fact that it could not in any conceivable way cause failure, even on the weakest tail plane. With the tail plane of thick section, however, the conditions were quite different, even though the average load was of course the same as before. A very high local down load occurred at the leading edge and conversely a very high up load occurred at the hinge, which consequently produced a very large torsional moment about the Y-axis of the airplane, so that this type of loading might prove structurally unsafe unless the front spar was made exceptionally stiff. It is also shown that there may be considerable danger in the use of an adjustable tail plane which can reduce the load on the controls to a very small amount, yet the load on the tail plane itself may be very large, in some cases dangerously so, without giving warning to the pilot. The advantages of an inverted tail plane—that is, a section with the greatest camber on the lower surface—are made evident from the pressure curves, which show a much more even distribution of pressure over the tail surfaces with this arrangement. The use of a tail plane of high aspect ratio is in some cases a structural advantage because it brings the tips of the tail surface outside of the slip stream, and it is the tip of the tail plane which carries a considerable proportion of the load; and if the tip is in the slip stream, as is the case with a great many tail planes, this load is considerably augmented. In this case the load may be upward on one side of the tail plane and down on the other, due to the rotation of the slip stream, producing a very large torque about the X-axis of the airplane, while with the high aspect ratio plane this torque is considerably reduced.

STABILITY.

The conclusions reached on stability may be summed up briefly by stating that the efficiency of the tail plane is increased by an increase in aspect ratio far more than by any other change, and this is proved not only by pressure distribution but by theory and by tests on the stability of the airplane from measurements of the elevator force and position. The center of pressure travel for the wings as determined from the integrated pressure on the tail surfaces give curves that are fairly consistent with themselves and with results obtained in another way by the British, but the center of pressure is slightly further forward on the full size airplane than it is on the model.

TABLE OF RESULTS.

	Revolutions per minute.	Air speed.	Center of pressure on whole tail, inches ahead of hinge.	Center of pressure on elevator, inches back of hinge.	Load on tail plane, in pounds per square foot.	Load on elevator, in pounds per square foot.	Total load, in pounds per square foot.	Maximum local load in pounds per square foot.	Moment about center line of tail, in inch-pounds.
CASE I	1,400	45	11	10	1.1	0.5	0.8	+ 7.1	
		50	3	12	.7	.6	.7	+ 8.1	
		60	3	7	.7	.5	.6	+ 7.7	
		70	− 57	− 8	.0	.3	.2	+ 0.8	
		80	− 37	12	.0	1.1	.5	+ 1.2	
	1,200	45	26	11	1.0	.1	.6	− 2.8	
		50	11	1	.4	.2	.4	+ 2.8	
		60	2	−23	.3	.1	.2	+ 5.2	
		70	60	67	.0	.1	.0	+ 7.0	
		80	18	18	1.4	.6	1.1	+ 9.9	
	900	45	− 34	19	.2	.8	.2	+ 9.1	
		50	27	30	.6	.0	.3	− 2.1	
		60	20	30	.0	.1	.1	+ 3.6	
		70	26	40	.6	.1	.4	+ 5.6	
		80	22	19	1.9	.4	1.2	+10.7	
		90	16	20	1.2	.6	.9	+ 8.1	
	600	45	6	15	1.2	.4	.9	− 3.7	
		50	22	− 8	1.2	.2	.8	− 2.9	
		60	21	− 4	.6	.1	.4	− 2.6	
		70	− ∞	10	.2	.3	.0	− 4.2	
		80	41	− 4	.8	.2	.6	+ 8.8	
		100	23	25	1.4	.3	1.0	+ 8.8	
CASE II	1,400	45	17	1	1.0	.0	.7	− 4.2	613
		50	7	11	.7	.4	.6	+ 5.5	568
		60	− 30	8	.1	.3	.2	+ 7.8	400
		70	−298	10	.3	.5	.0	+10.8	406
		80	47	− 4	1.0	.2	.5	+13.6	549
	1,200	45	13	20	.7	.3	.5	− 2.9	
		50	10	18	.5	.2	.3	− 2.9	
		60	11	8	.7	.3	.6	+ 4.7	242
		70	− 14	16	.0	.1	.0	+ 6.5	
		80	38	−80	.7	.0	.4	+ 9.4	
	900	45	10	−13	1.0	.1	.5	− 3.1	
		50	27	8	.7	.1	.4	− 2.6	
		60	− 48	33	.0	.1	.0	+ 3.1	307
		70	− 20	27	.1	.0	.1	+ 3.1	
		80	39	8	.7	.1	.4	+ 6.5	
		90	28	16	1.8	.2	1.1	+ 9.9	
	600	45	43	3	.9	.3	.4	− 3.1	
		50	55	14	.7	.4	.3	− 1.8	
		60	37	4	.3	.1	.1	+ 2.3	284
		70	−216	23	.0	.1	.0	+ 3.1	
		80	25	12	1.1	.2	.7	+ 6.8	
		100	29	160	1.7	.0	1.0	+11.5	
CASE III	1,400	45	− 2	12	.6	.7	.6	+ 6.5	432
		50	− 11	11	.4	.8	.6	+ 7.8	619
		60	∞	0.5	.4	.4	.0	+ 9.6	1,216
		70	356	9	−.6	.4	.1	+12.3	534
		80	99	9	1.3	1	.4	+14.6	392
	1,200	45	8	12	.9	.6	.8	+ 2.9	
		50	− 3	11	.4	.6	.5	+ 4.4	87
		60	− 40	10	.0	.8	.3	+13	
		70	131	13	.7	.6	.0	+ 9.1	
		80	51	11	1.5	.6	.6	+11.5	
	900	45	14	29	.6	.2	.4	− 2.1	
		50	10	18	.6	.1	.5	− 1.8	27
		60	140	11	.3	.1	.0	+ 3.7	
		70	53	8	1.2	.5	.5	+ 7.8	
		80	44	11	1.5	.5	.7	+ 8.3	
		90	55	12	1.5	.6	.6	+ 8.3	

+ Down loading. − Up loading.

TABLE OF RESULTS—Continued.

	Revolutions per minute.	Air speed.	Center of pressure on whole tail, inches ahead of hinge.	Center of pressure on elevator, inches back of hinge.	Load on tail plane, in pounds per square foot.	Load on elevator, in pounds per square foot.	Total load, in pounds per square foot.	Maximum local load in pounds per square foot.	Moment about center line of tail, in inch-pounds.
CASE III	600	45	21	12	0.9	10	0.6	− 3.1	
		50	21	10	.6	10	.4	− 1.6	152
		60	− 64	14	.1	.5	.1	+ 1.8	
		70	195	10	.5	.5	.1	+ 5.2	
		80	53	13	1.1	.5	.4	+ 6.8	
		100	32	45	2.1	.1	1.2	+12.3	
CASE IV	1,400	45	4	11	.7	.5	.6	+ 6.5	
		50	5	12	.6	.9	.7		
		60	− 29	12	.1	.7	.4		
		70	124	7	.8	.7	.2		
		80	123	10	1.3	1.0	.3		839
	1,200	45	7	10	.7	.4	.5		
		50	− 5	11	.5	.6	.5		
		60	− 31	10	.0	.6	.6	+ 6.0	
		70	− 53	12	.1	.8	.3		
		80	84	13	.7	.4	.3		
	900	45	19	21	.9	.2	.5		
		50	13	12	.6	.3	.5		
		60	− 1	11	.4	.4	.4		
		70	− 26	15	.0	.6	.4		
		80	− 45	10	.0	.8	.3	+ 6.8	
		90	34	− 16	1.5	.1	.8		
	600	45	16	22	1.2	.4	.8		
		50	16	9	.6	.2	.4		
		60	1	17	.2	.1	.2		
		70	145	8	.2	.2	.0		
		80	−176	13	.4	.8	.1		
		100	43	12	2.5	.7	1.1	+15.6	
CASE V	1,400	45	23	−130	.5	.0	.3	+ 3.1	157
		50	59	11	1.1	.7	.4	+ 5.2	545
		60	57	11	1.3	.7	.5	+ 6.8	566
		70	25	176	2.9	.0	1.6	+ 6.8	845
		80	24	38	3.8	.2	2.3	+ 9.4	1,673
	1,200	45			.6	.1	.4	− 3.7	
		50			.7	.3	.3	− 3.1	
		60	48	11	1.3	.5	.5	+ 3.9	
		70			2.2	.2	1.2	+ 6.5	
		80			2.9	.4	1.5	+ 8.3	
	900	45	64	70	.0	.0	.0	− 2.8	
		50	5	16	.2	.1	.2	− 2.8	
		60	21	45	.8	.0	.5	+ 2.1	
		70	32	2	1.6	.3	.8	+ 4.2	
		80	25	6	3.5	.1	2.0	+ 7.0	
		90	23	− 2	3.9	.2	2.1	+10.8	
	600	45	− 65	9	.1	.6	.2	− 4.2	
		50	− 7	11	.2	.2	.2	− 2.6	
		60	35	6	.5	.1	.3	+ 1.5	
		70	69	13	1.1	.7	.3	+ 4.4	
		80	31	− 4	1.9	.2	1.0	+ 6.2	
		100	29	1	3.6	.2	2.0	+ 8.3	
CASE VI	1,400	45						− 8.6	
		50						− 8.3	
		60						− 9.1	
		70						−12.6	
		80						−14.6	
	600	50						− 4.7	
		60						− 3.9	
		70						+ 6.5	
		80						+10.8	
		100						+15.6	

\+ Down loading. — Up loading.

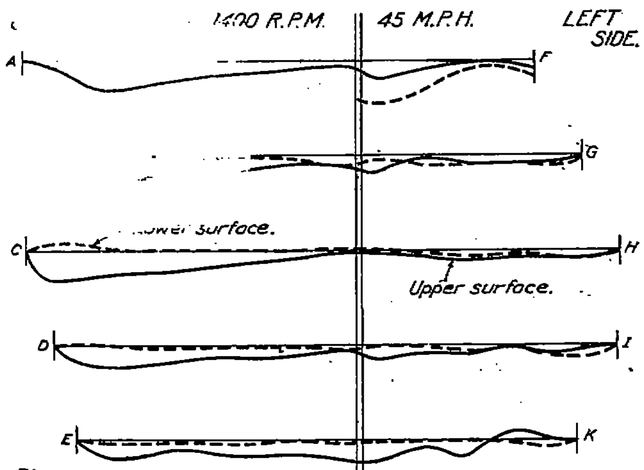


Fig. 36.

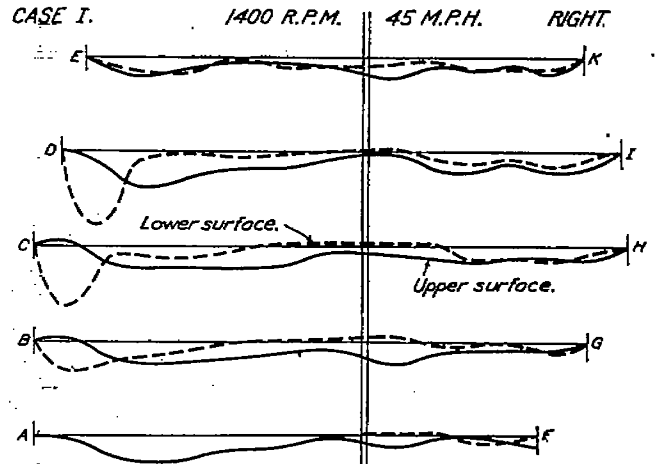


Fig. 41.

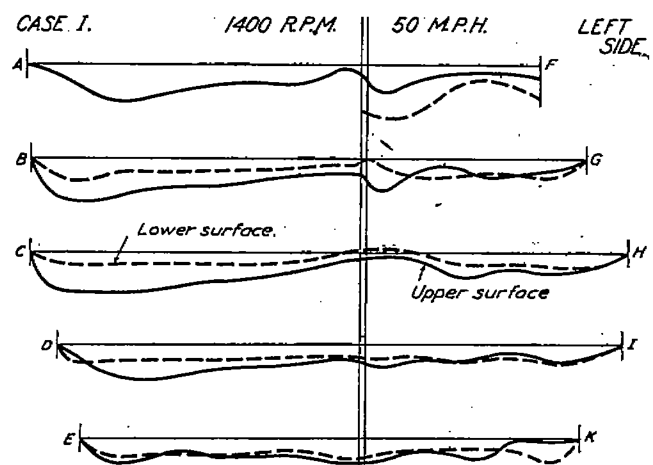


Fig. 37.

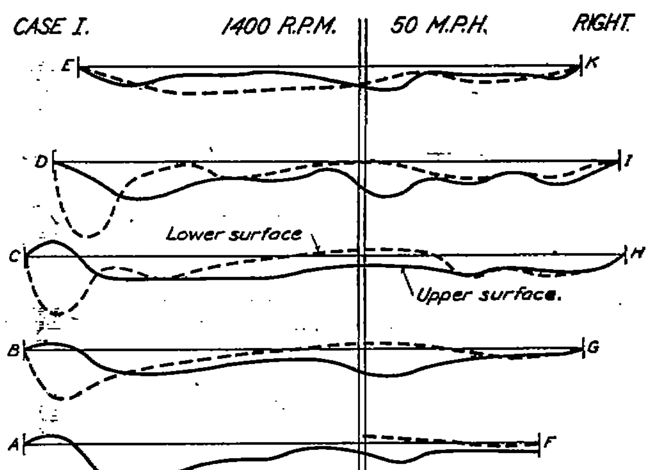


Fig. 42.

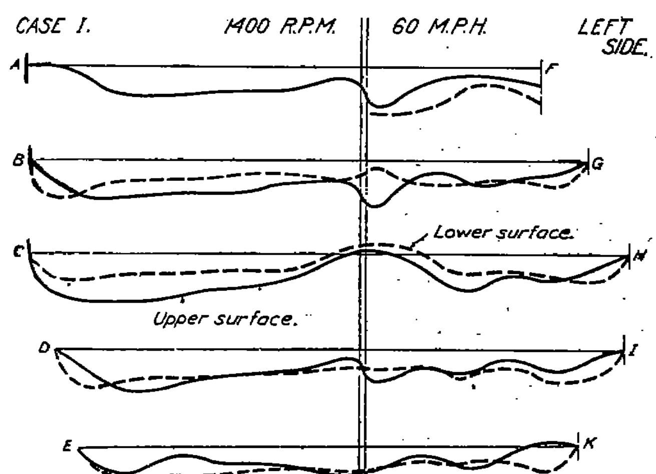


Fig. 38.

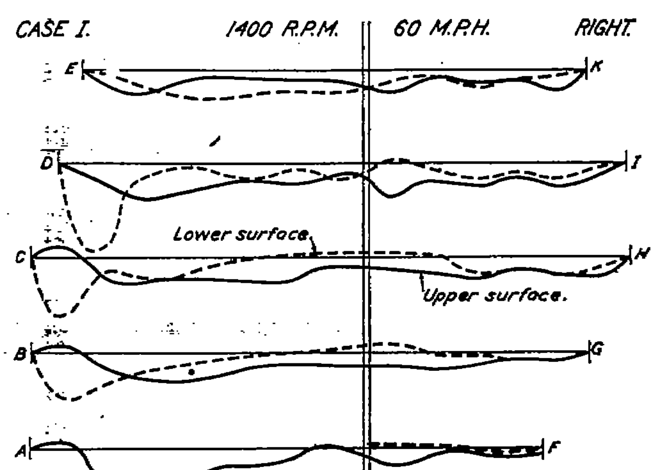


Fig. 43.

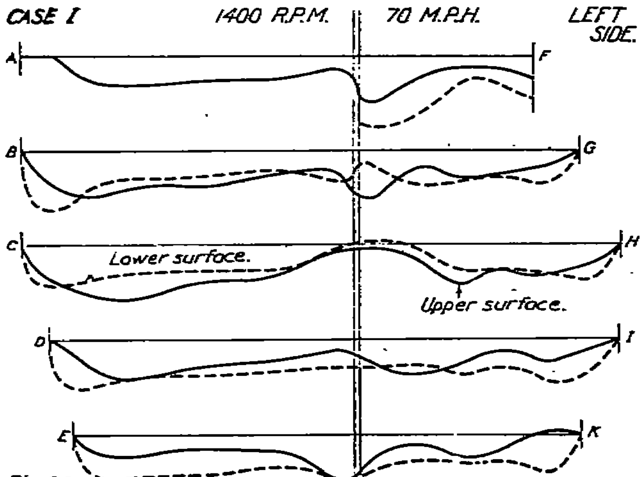


Fig. 39.

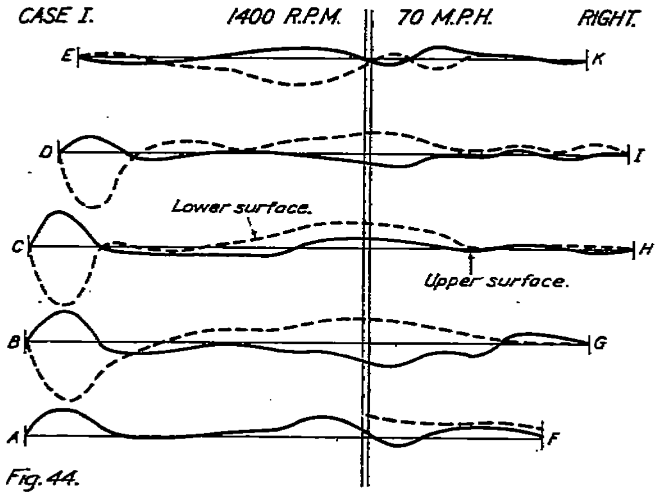


Fig. 44.

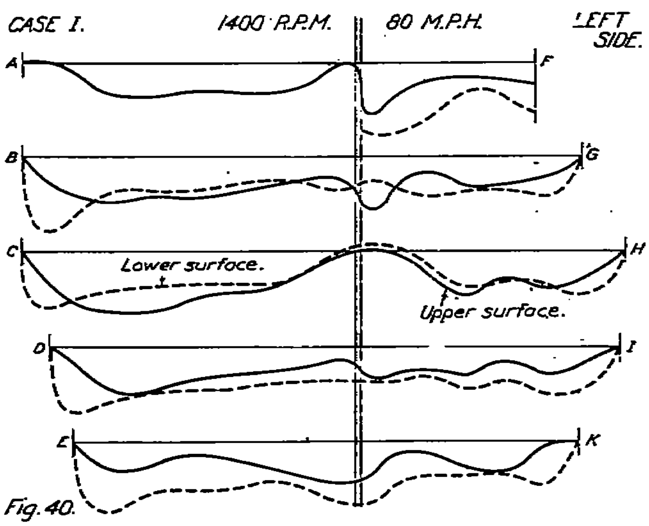


Fig. 40.

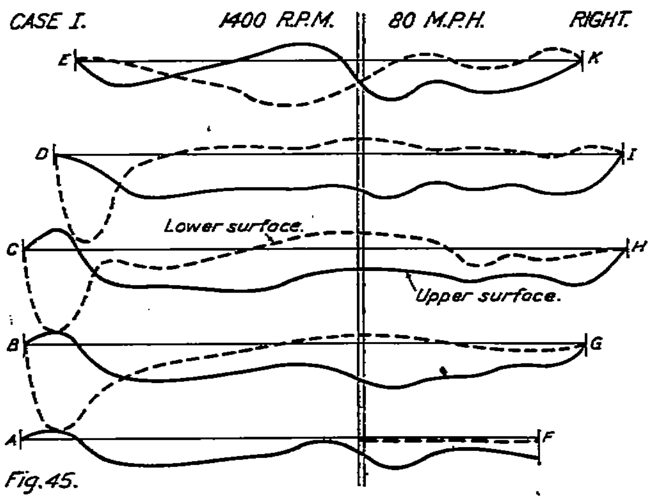


Fig. 45.

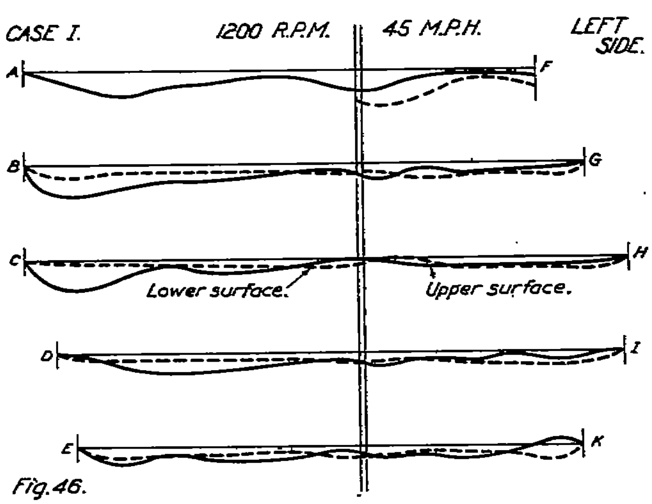


Fig. 46.

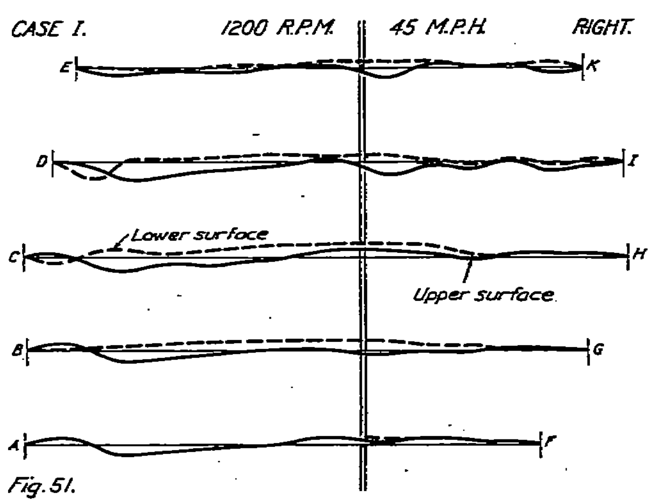


Fig. 51.

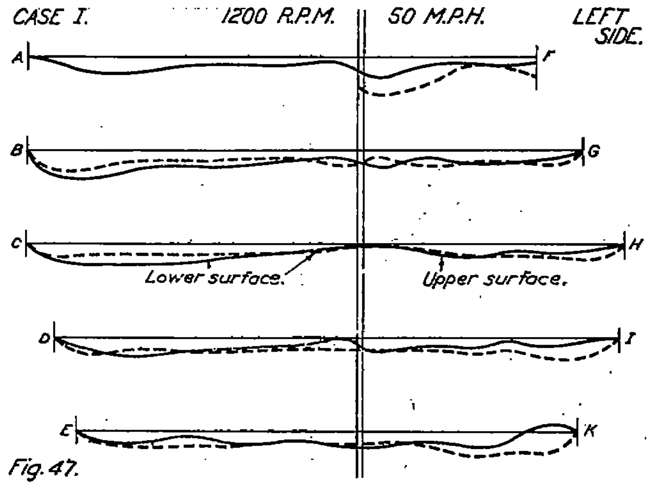


Fig. 47.

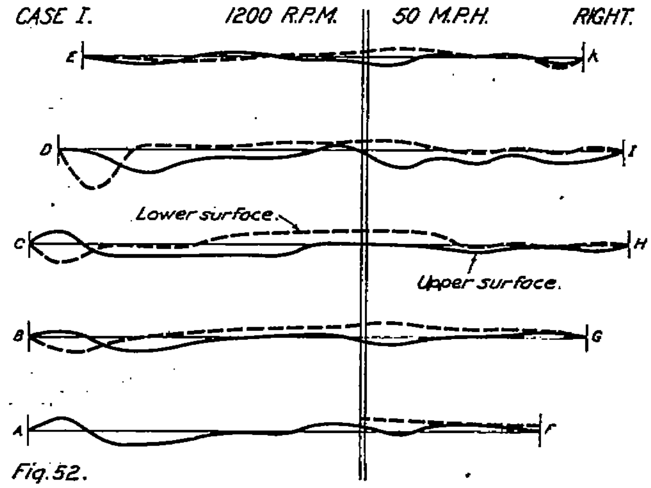


Fig. 52.

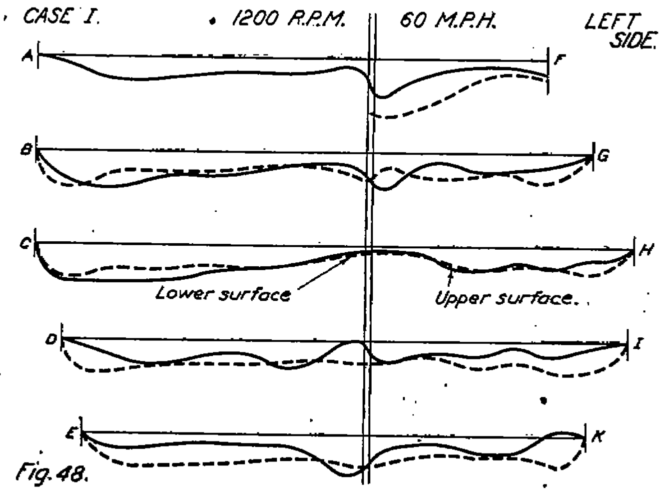


Fig. 48.

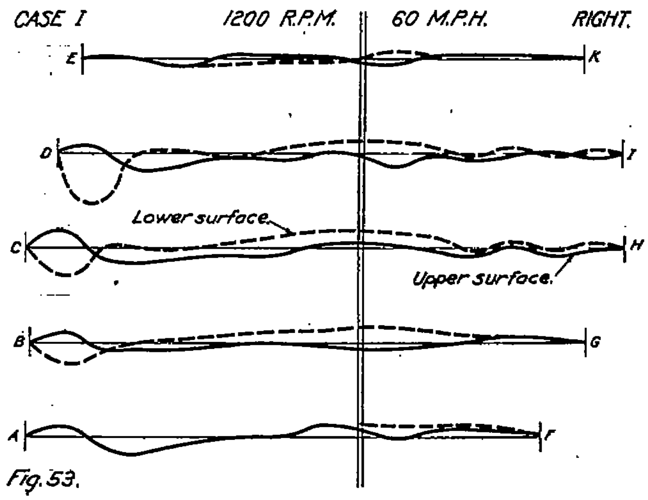


Fig. 53.

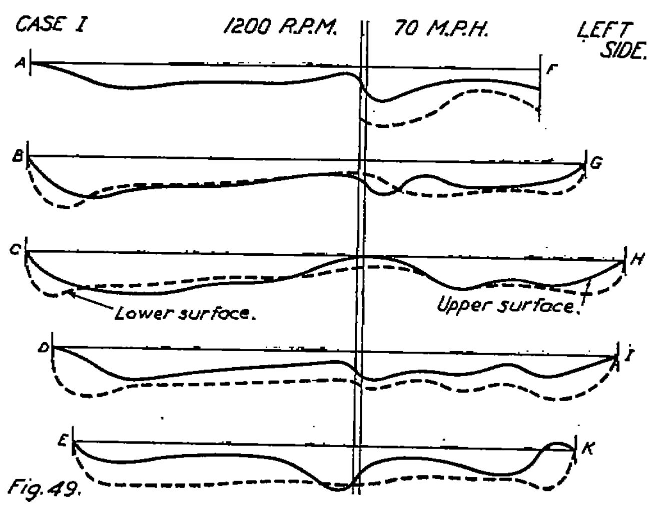


Fig. 49.

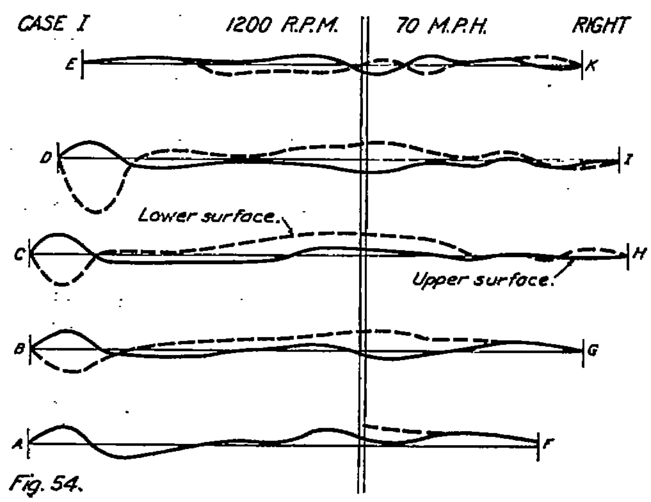


Fig. 54.

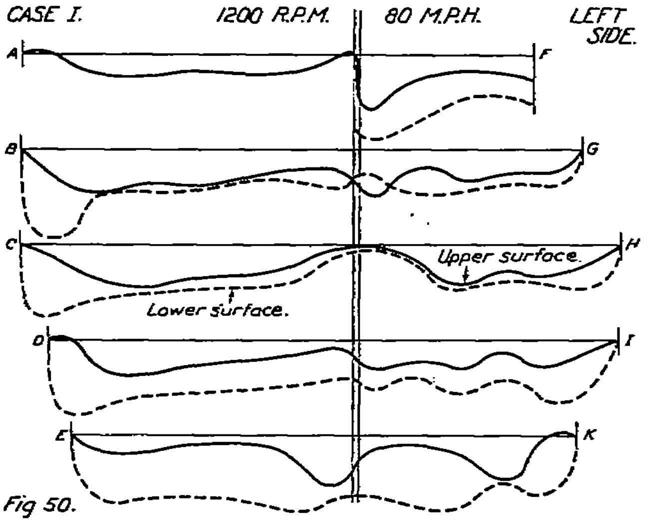


Fig 50.

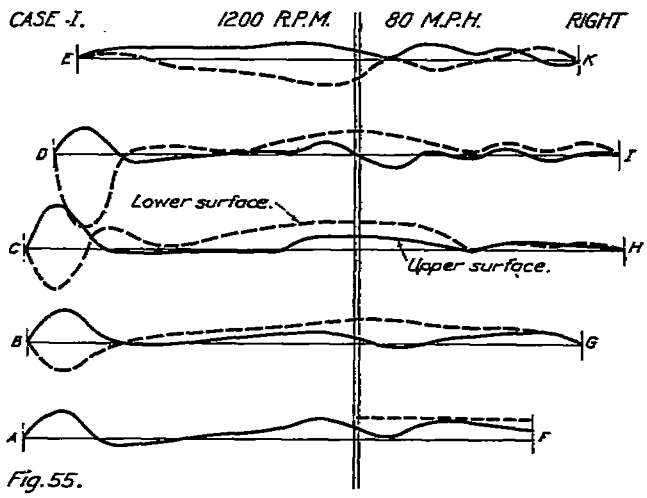


Fig. 55.

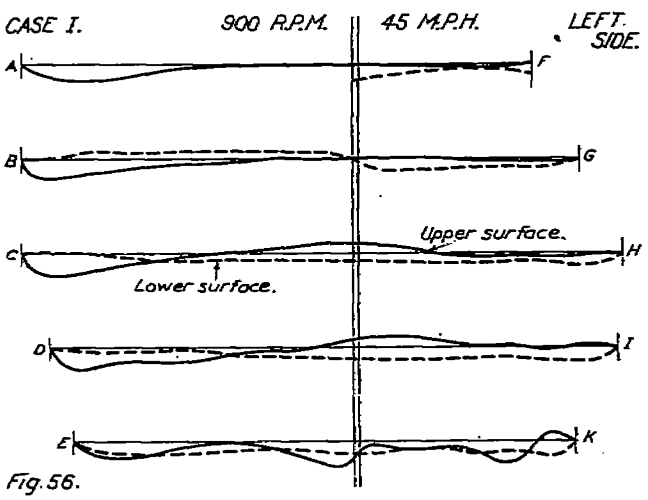


Fig. 56.

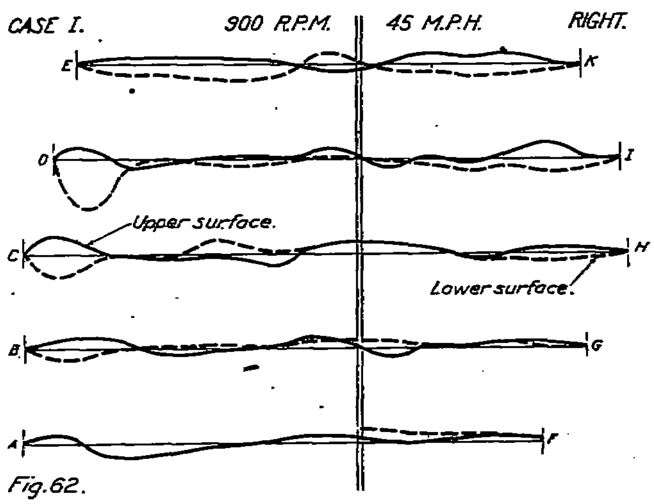


Fig. 62.

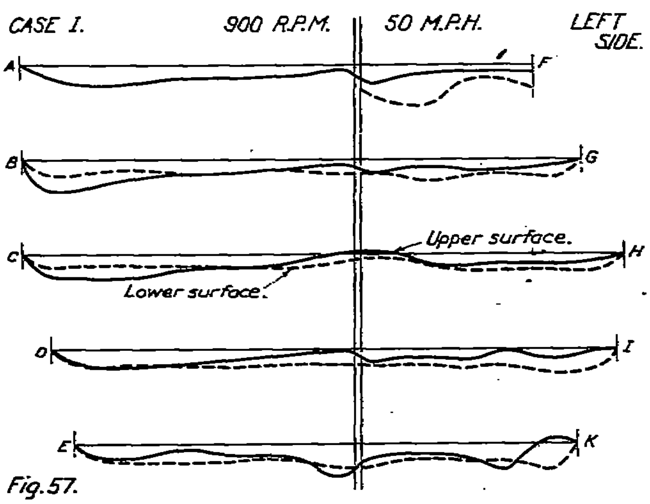


Fig. 57.

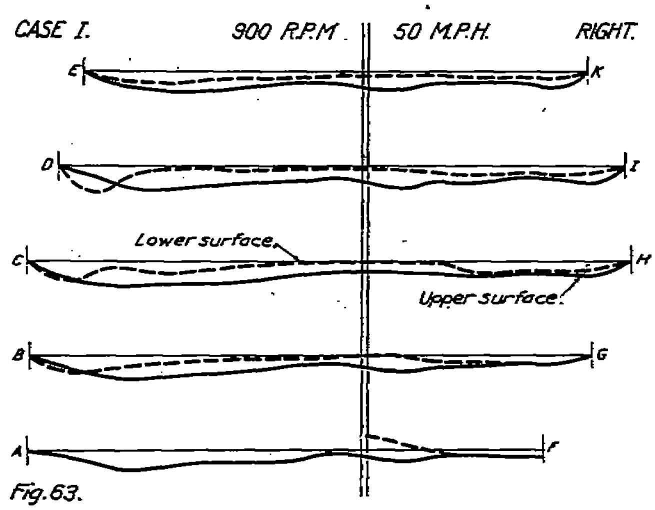


Fig. 63.

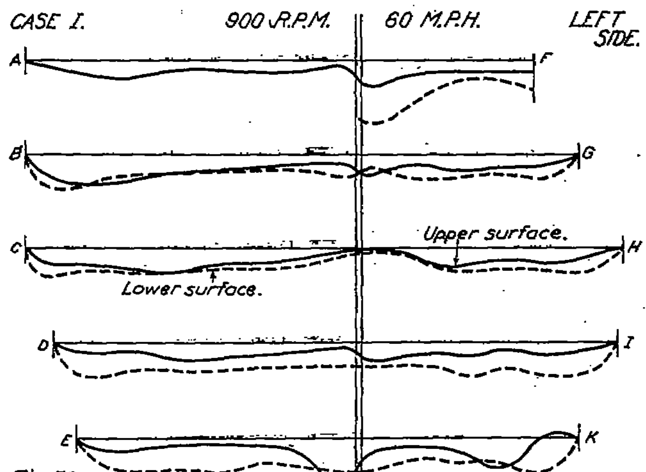


Fig. 58.

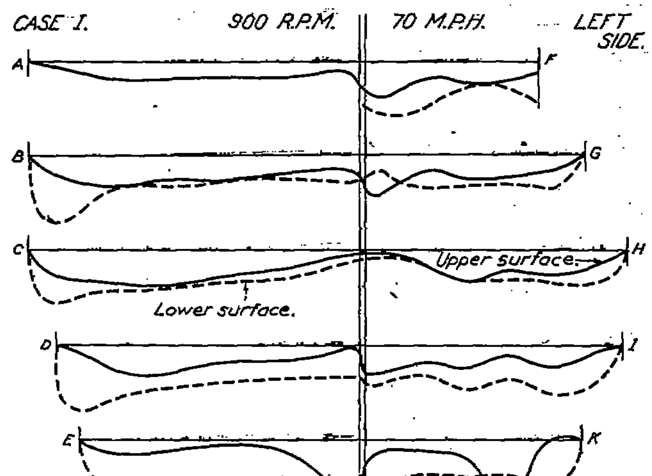


Fig. 59.

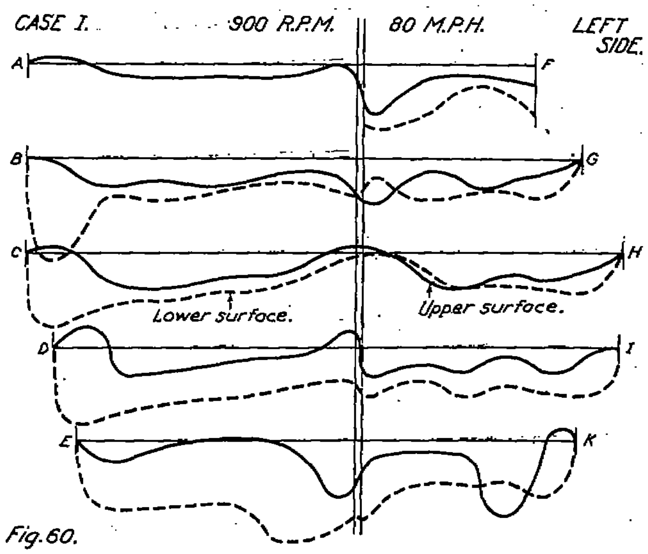


Fig. 60.

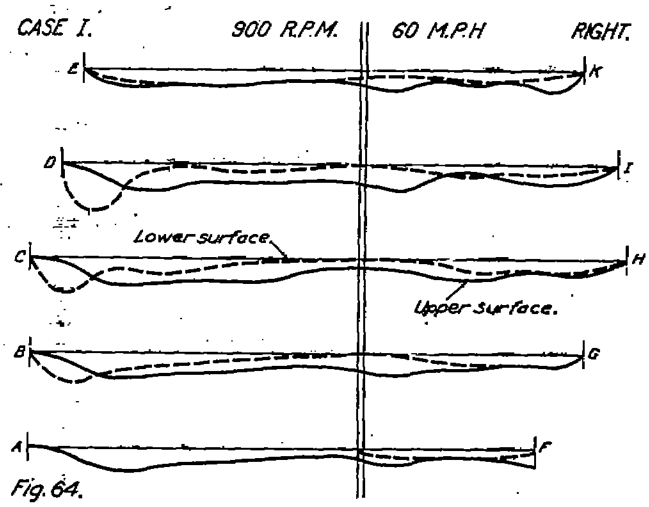


Fig. 64.

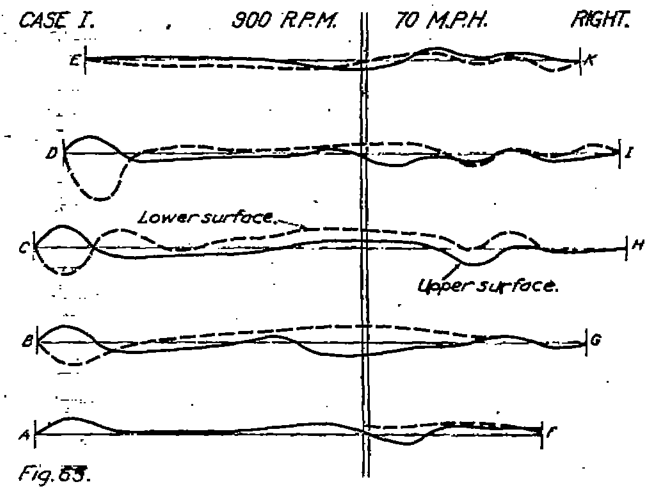


Fig. 65.

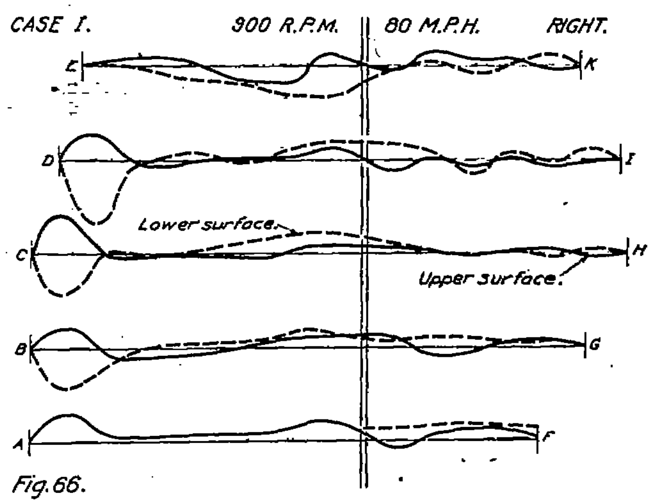


Fig. 66.

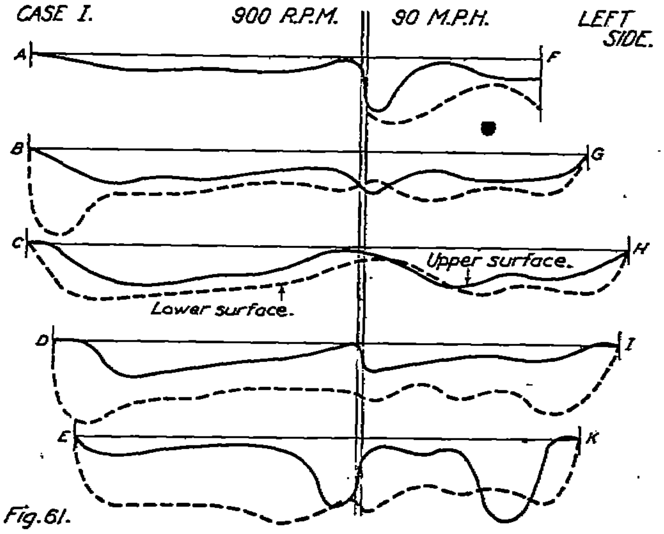


Fig. 61.

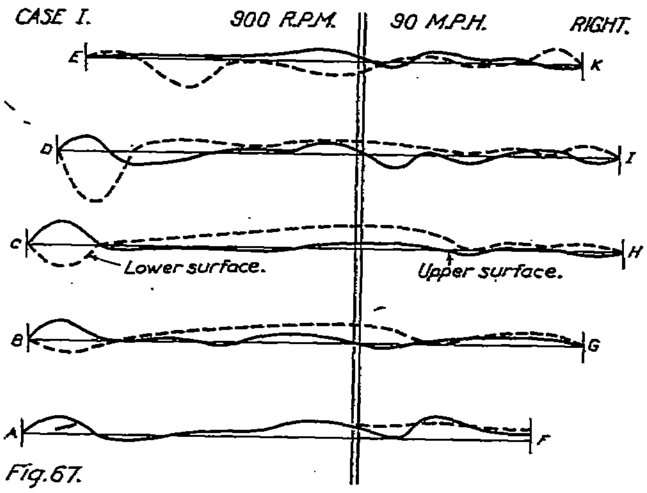


Fig. 67.

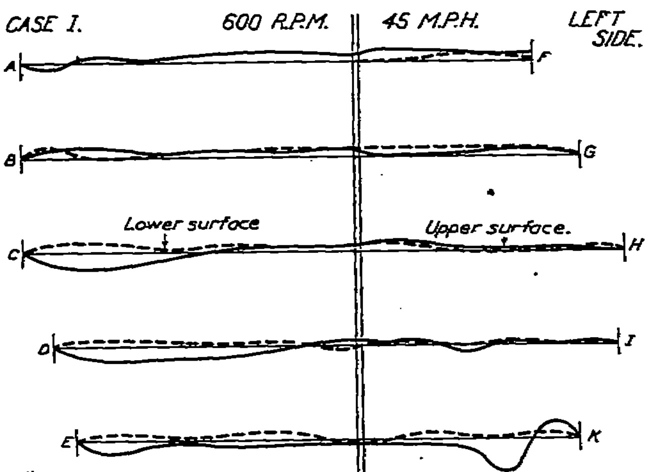


Fig. 68.

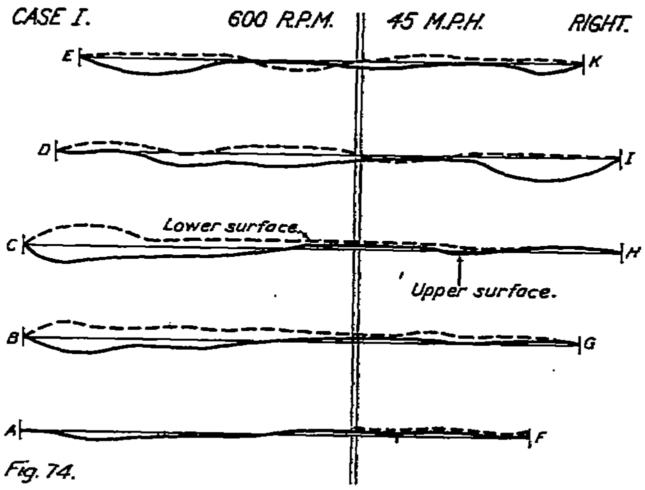


Fig. 74.

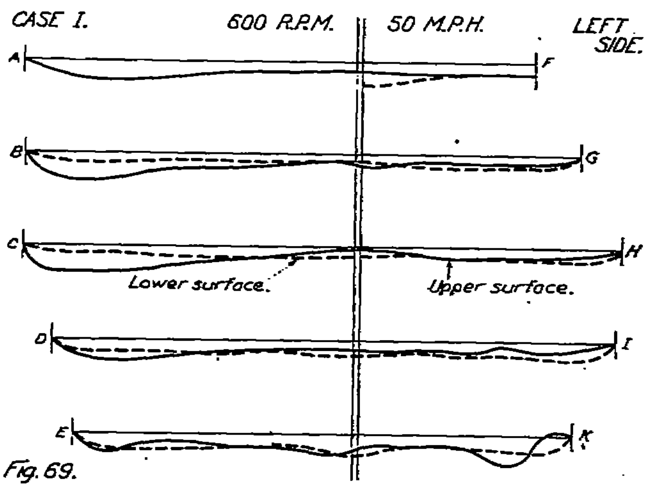


Fig. 69.

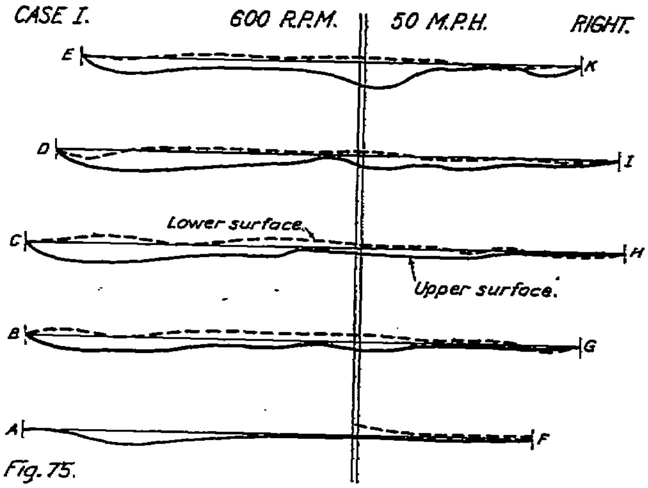


Fig. 75.

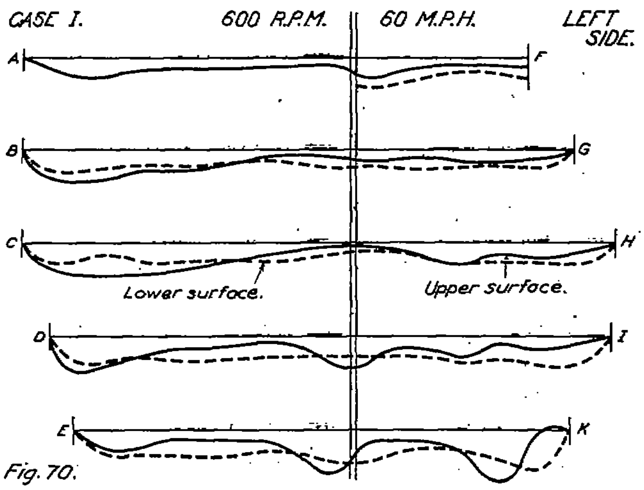


Fig. 70.

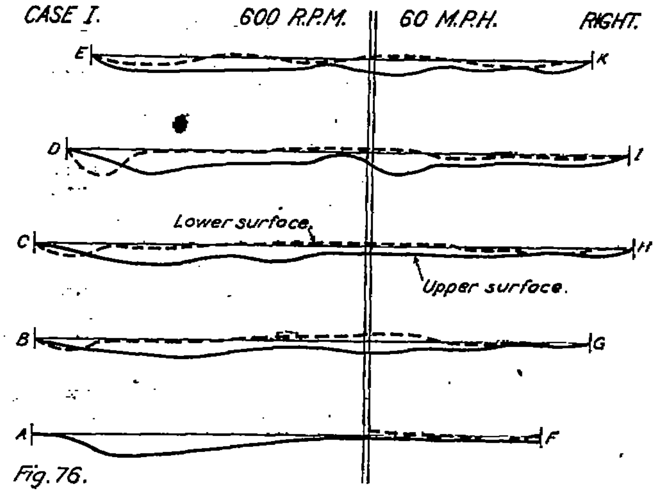


Fig. 76.

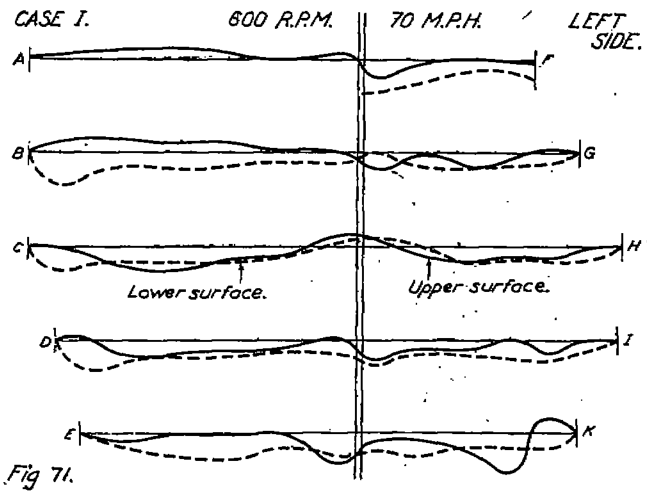


Fig 71.

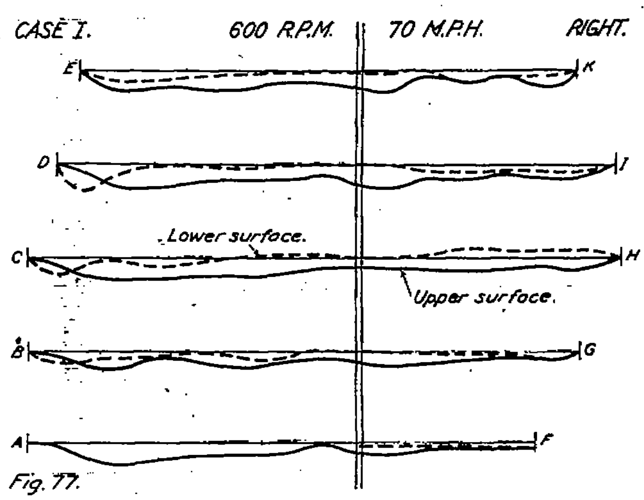


Fig. 77.

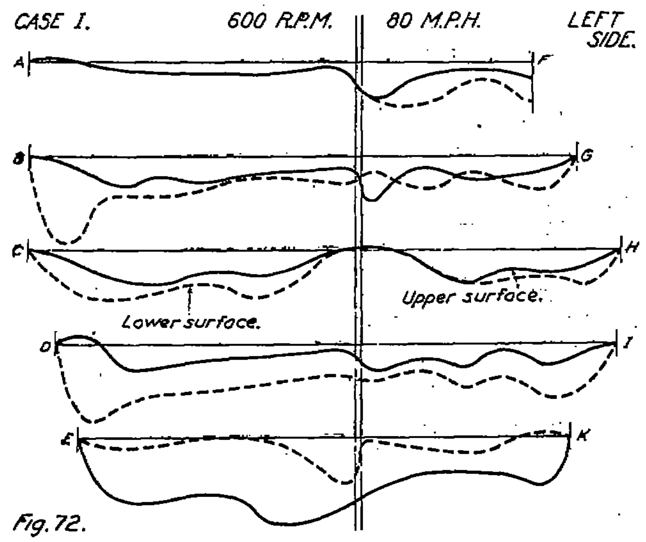


Fig. 72.

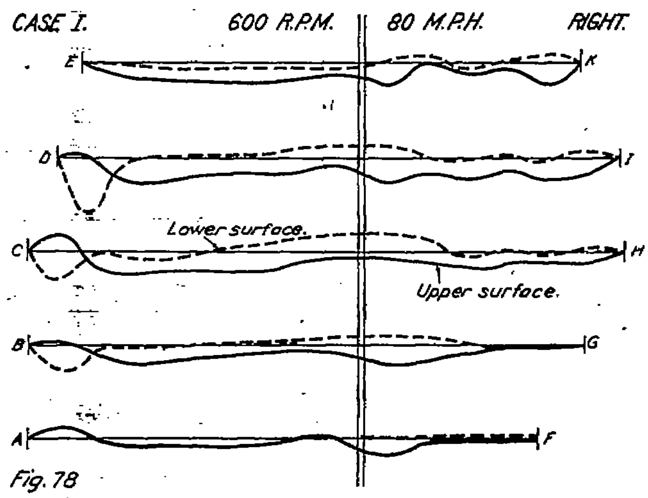
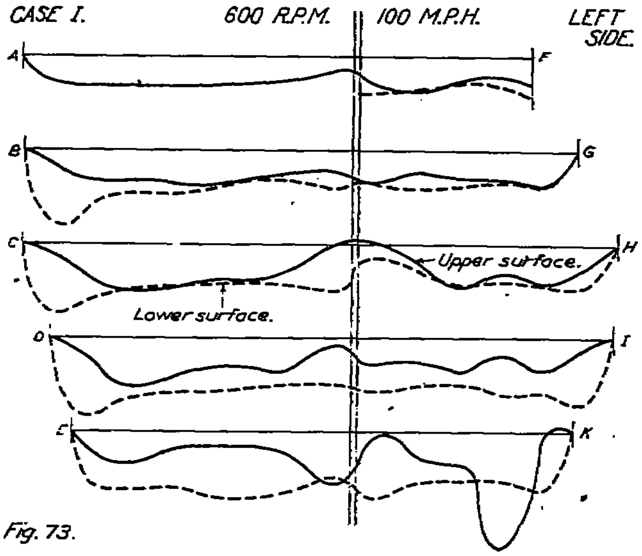
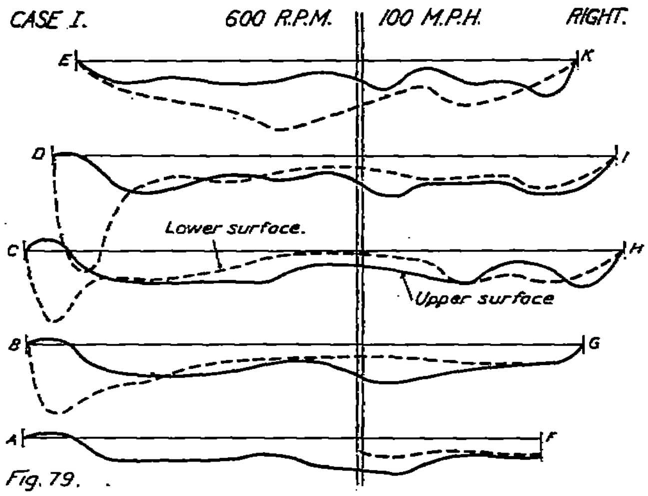


Fig. 78


CASE I.
600 R.P.M.
100 M.P.H.
LEFT SIDE.
A
F
B
G
C
H
Upper surface.
Lower surface.
D
I
E
K
Fig. 73.


CASE I.
600 R.P.M.
100 M.P.H.
RIGHT.
E
K
D
I
Lower surface.
C
H
Upper surface
B
G
A
F
Fig. 79.

CASE I. 1400 R.P.M. 45 M.P.H.

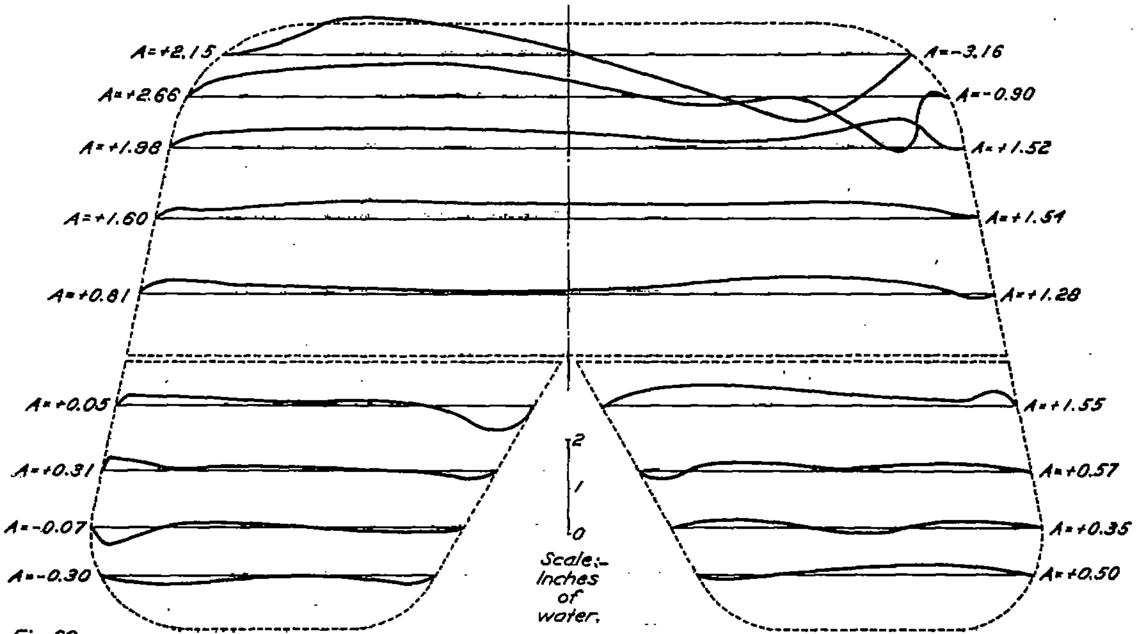


Fig. 80.

CASE I. 1400 R.P.M. 50 M.P.H.

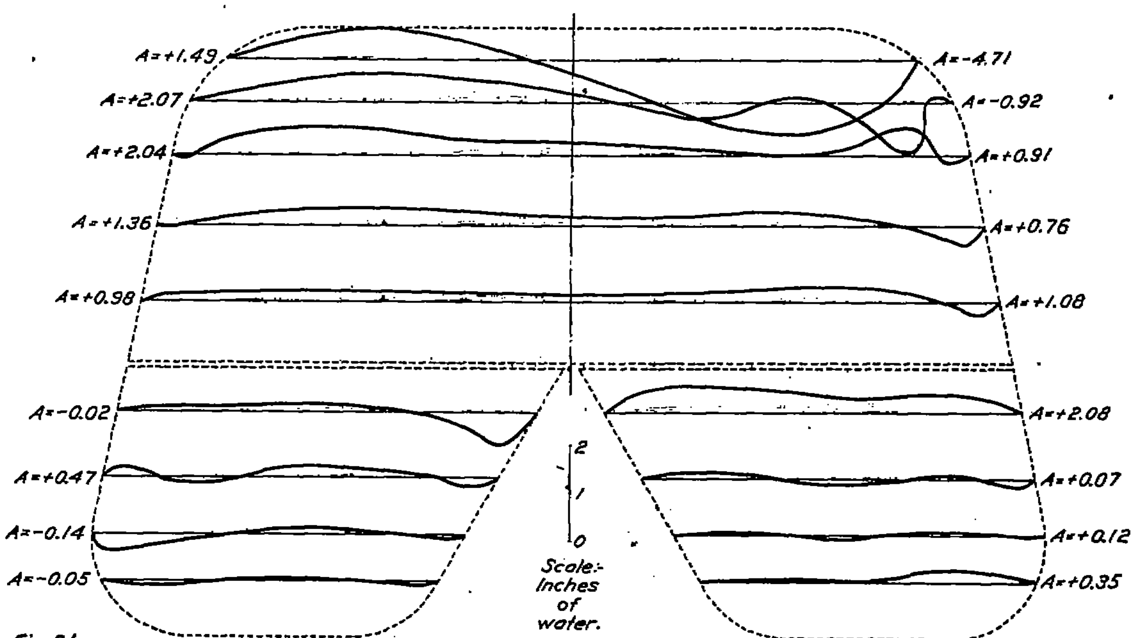


Fig. 81.

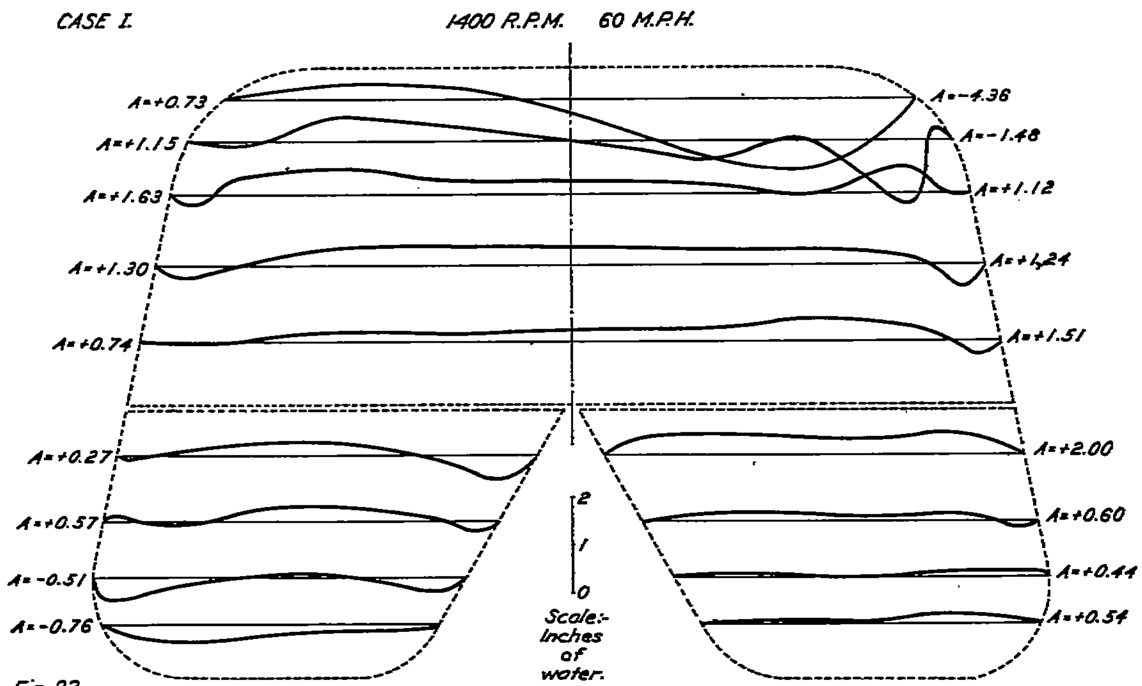

CASE I.
1400 R.P.M. 60 M.P.H.
A=+0.73
A=+1.15
A=+1.63
A=+1.30
A=+0.74
A=-4.36
A=-1.48
A=+1.12
A=+1.24
A=+1.51
A=+0.27
A=+0.57
A=-0.51
A=-0.76
A=+2.00
A=+0.60
A=+0.44
A=+0.54
2
1
0
Scale:-
Inches
of
water.

Fig. 82.

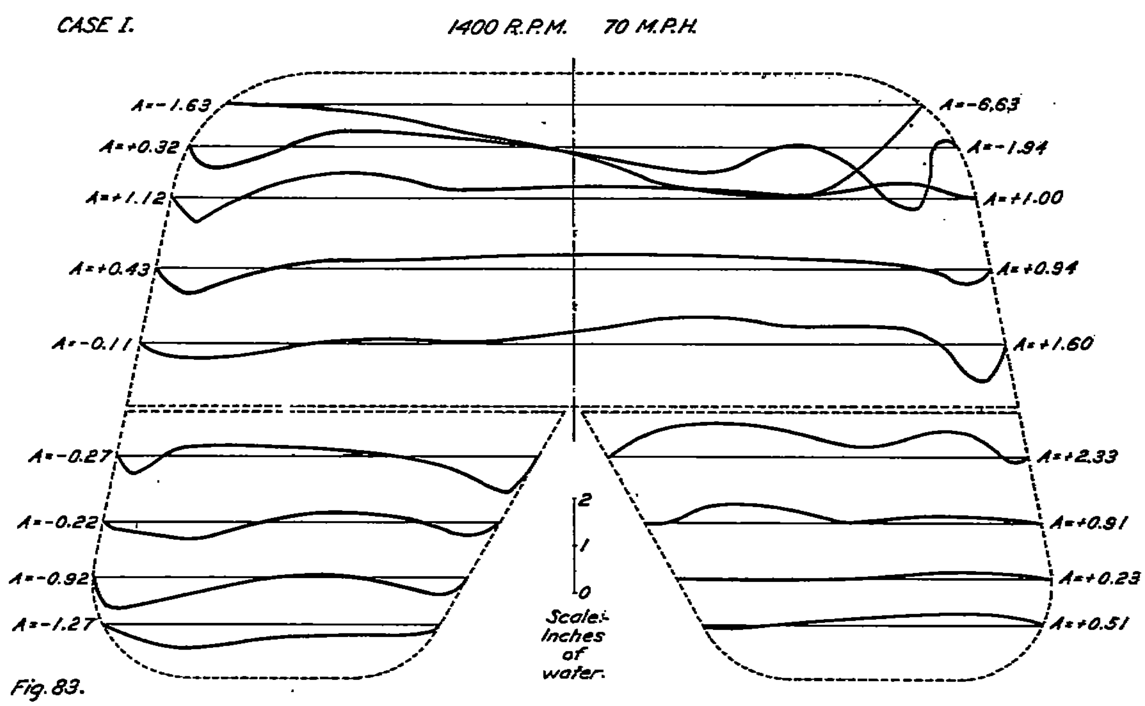

CASE I.
1400 R.P.M. 70 M.P.H.
A=-1.63
A=+0.32
A=+1.12
A=+0.43
A=-0.11
A=-6.63
A=-1.94
A=+1.00
A=+0.94
A=+1.60
A=-0.27
A=-0.22
A=-0.92
A=-1.27
A=+2.33
A=+0.91
A=+0.23
A=+0.51
2
1
0
Scale:-
Inches
of
water.

Fig. 83.

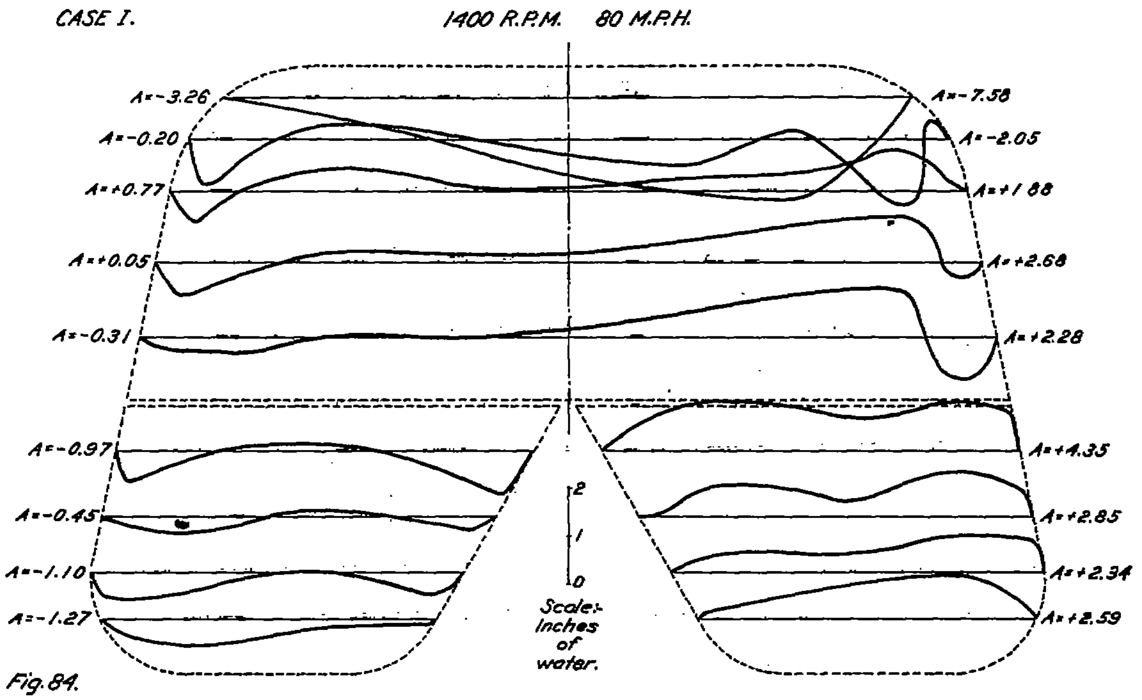

CASE I.
1400 R.P.M. 80 M.P.H.
A=-3.26
A=-0.20
A=+0.77
A=+0.05
A=-0.31
A=-7.58
A=-2.05
A=+1.88
A=+2.68
A=+2.28
A=-0.97
A=-0.45
A=-1.10
A=-1.27
A=+4.35
A=+2.85
A=+2.34
A=+2.59
2
1
0
Scale:- Inches of water.

Fig. 84.

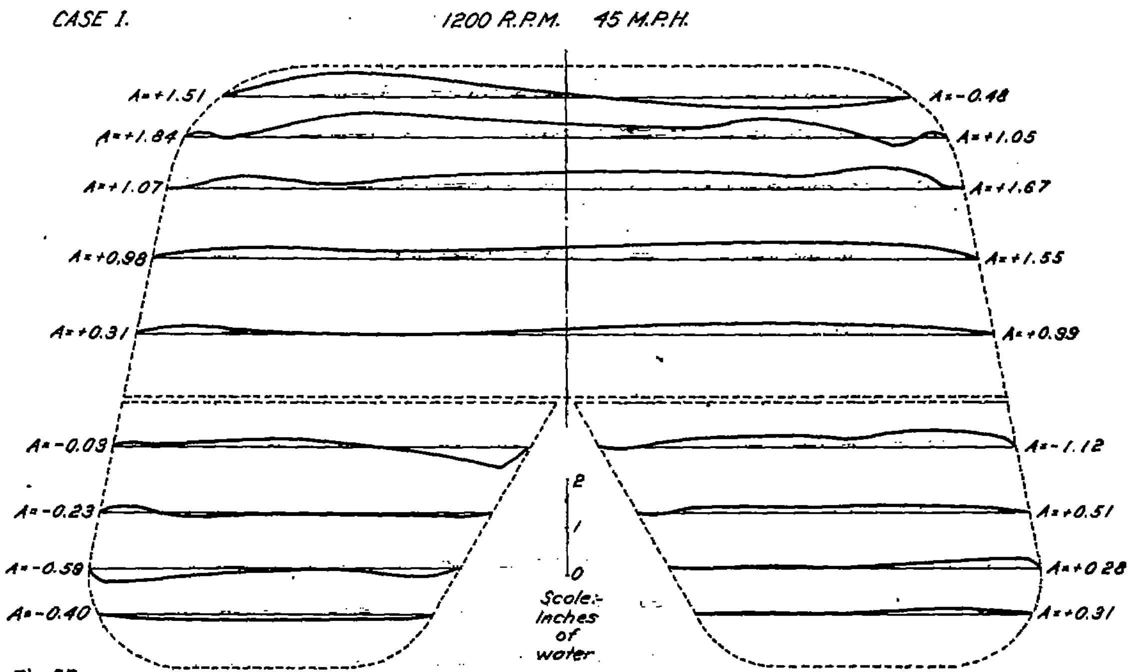

CASE I.
1200 R.P.M. 45 M.P.H.
A=+1.51
A=+1.84
A=+1.07
A=+0.98
A=+0.31
A=-0.48
A=+1.05
A=+1.67
A=+1.55
A=+0.99
A=-0.03
A=-0.23
A=-0.58
A=-0.40
A=-1.12
A=+0.51
A=+0.28
A=+0.31
2
1
0
Scale:- Inches of water

Fig. 85.

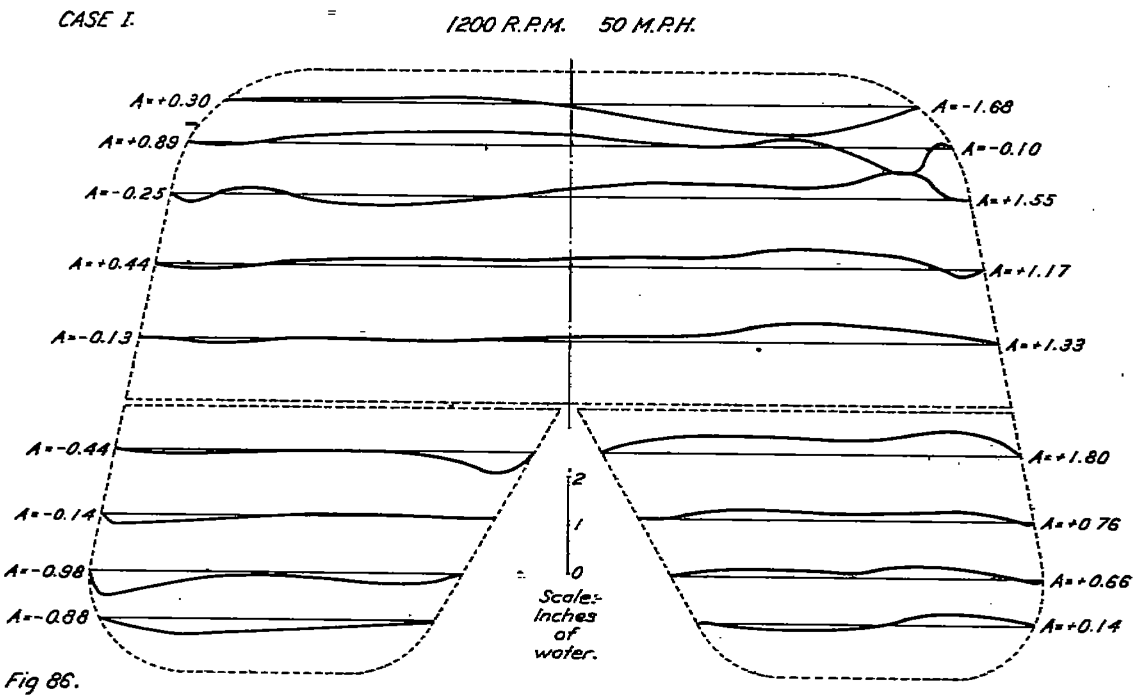

CASE I.
1200 R.P.M. 50 M.P.H.
A=+0.30
A=+0.89
A=-0.25
A=+0.44
A=-0.13
A=-0.44
A=-0.14
A=-0.98
A=-0.88
A=-1.68
A=-0.10
A=+1.55
A=+1.17
A=+1.33
A=+1.80
A=+0 76
A=+0.66
A=+0.14
2
1
0
Scale:-
Inches
of
water.

Fig 86.

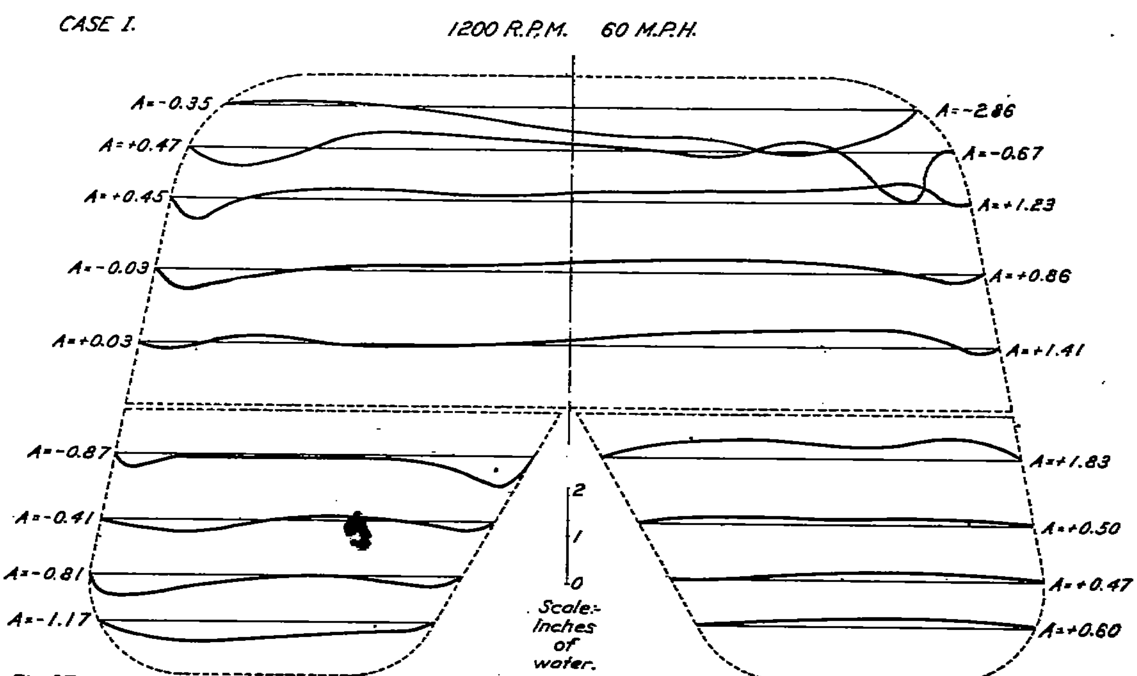
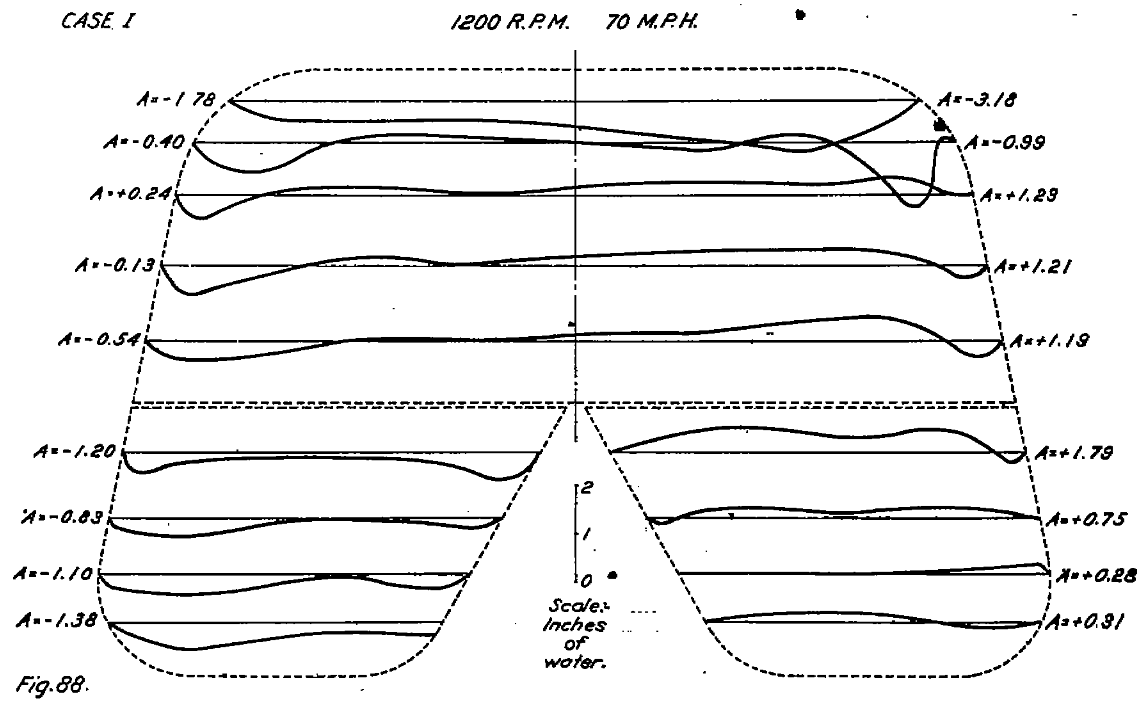
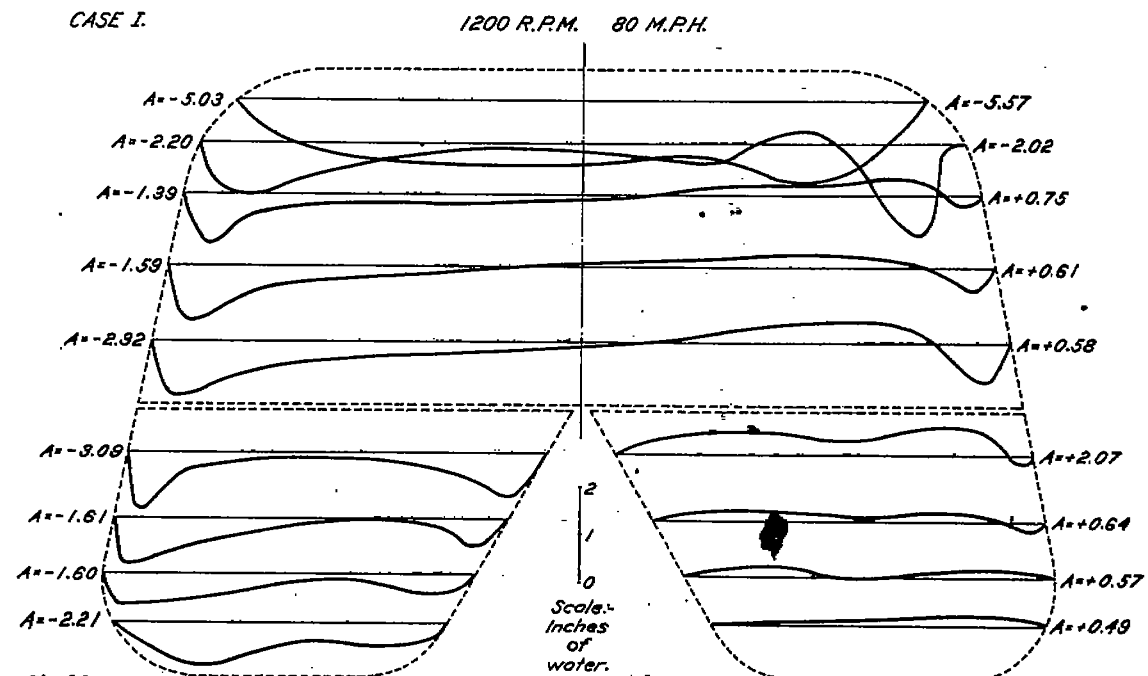

CASE I.
1200 R.P.M. 60 M.P.H.
A=-0.35
A=+0.47
A=+0.45
A=-0.03
A=+0.03
A=-0.87
A=-0.41
A=-0.81
A=-1.17
A=-2.86
A=-0.67
A=+1.23
A=+0.86
A=+1.41
A=+1.83
A=+0.50
A=+0.47
A=+0.60
2
1
0
Scale:-
Inches
of
water.

Fig. 87.


CASE I
1200 R.P.M. 70 M.P.H.
A=-1.78
A=-3.18
A=-0.40
A=-0.99
A=+0.24
A=+1.23
A=-0.13
A=+1.21
A=-0.54
A=+1.19
A=-1.20
A=+1.79
A=-0.83
A=+0.75
A=-1.10
A=+0.28
A=-1.38
A=+0.31
2
1
0
Scale:-
Inches
of
water.
Fig. 88.


CASE I.
1200 R.P.M. 80 M.P.H.
A=-5.03
A=-5.57
A=-2.20
A=-2.02
A=-1.39
A=+0.75
A=-1.59
A=+0.61
A=-2.92
A=+0.58
A=-3.09
A=+2.07
A=-1.61
A=+0.64
A=-1.60
A=+0.57
A=-2.21
A=+0.49
2
1
0
Scale:-
Inches
of
water.
Fig. 89.

CASE I. 900 R.P.M. 45 M.P.H.

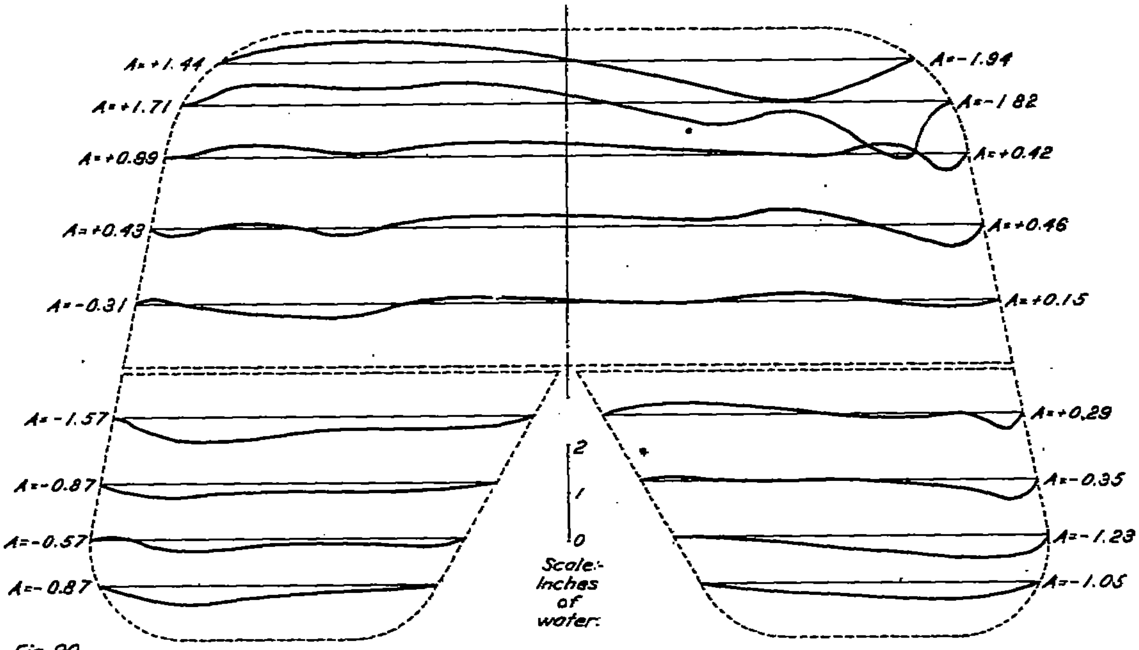


Fig. 90.

CASE I. 900 R.P.M. 50 M.P.H.

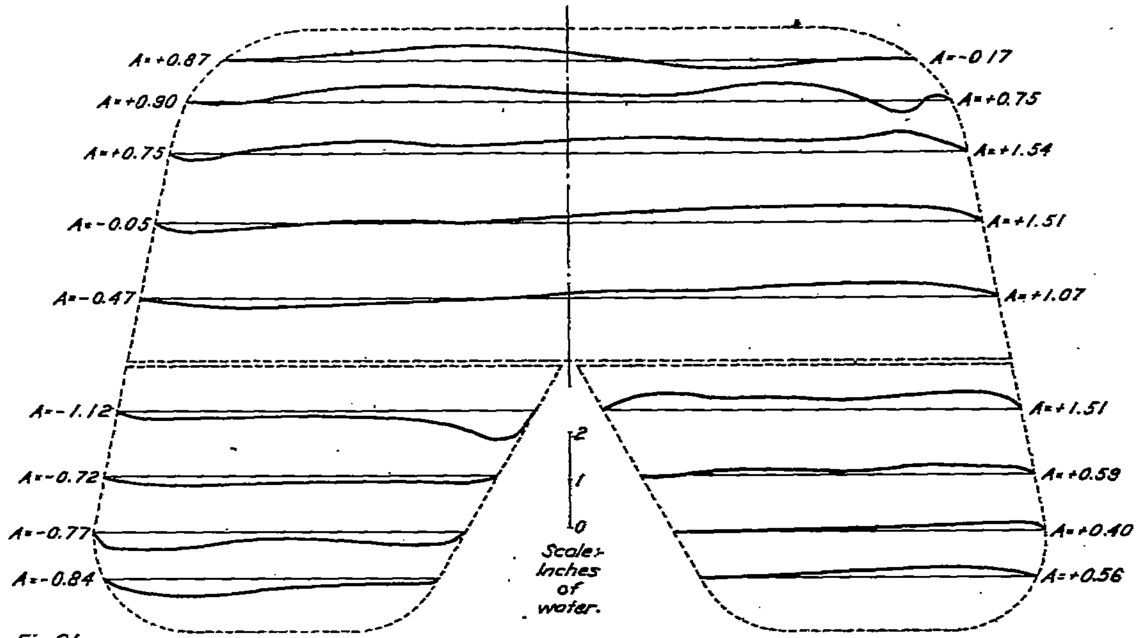


Fig. 91.

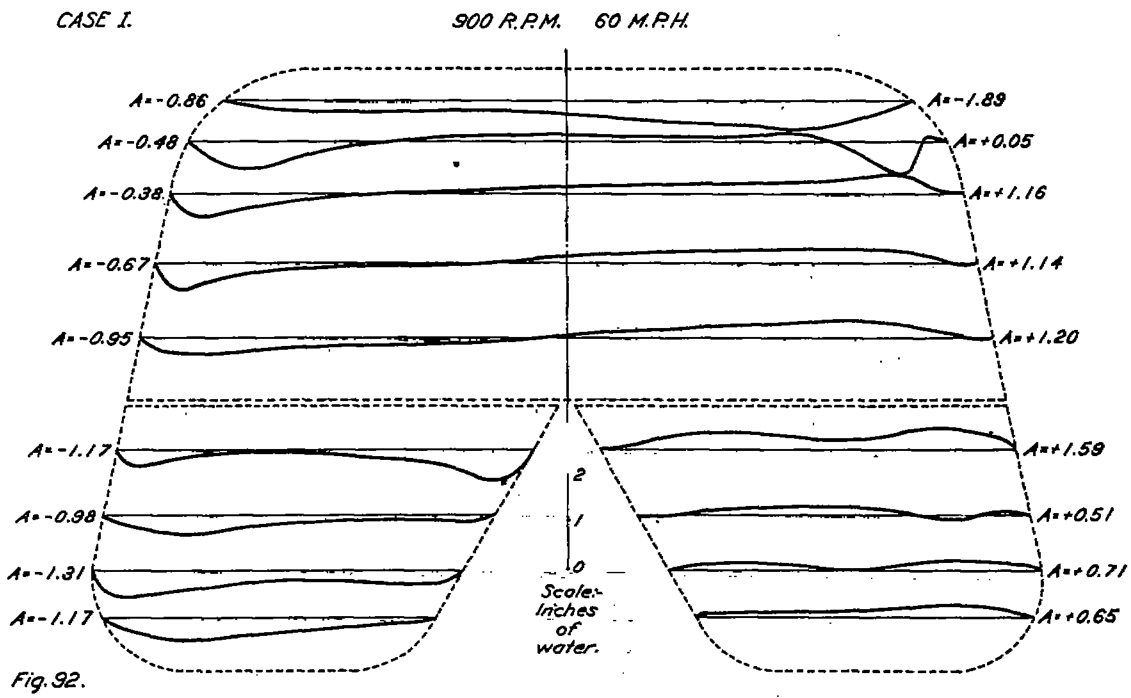

CASE I.
900 R.P.M. 60 M.P.H.
A=-0.86
A=-1.89
A=-0.48
A=+0.05
A=-0.38
A=+1.16
A=-0.67
A=+1.14
A=-0.95
A=+1.20
A=-1.17
A=+1.59
A=-0.98
A=+0.51
A=-1.31
A=+0.71
A=-1.17
A=+0.65
2
1
0
Scale:- Inches of water.

Fig. 92.

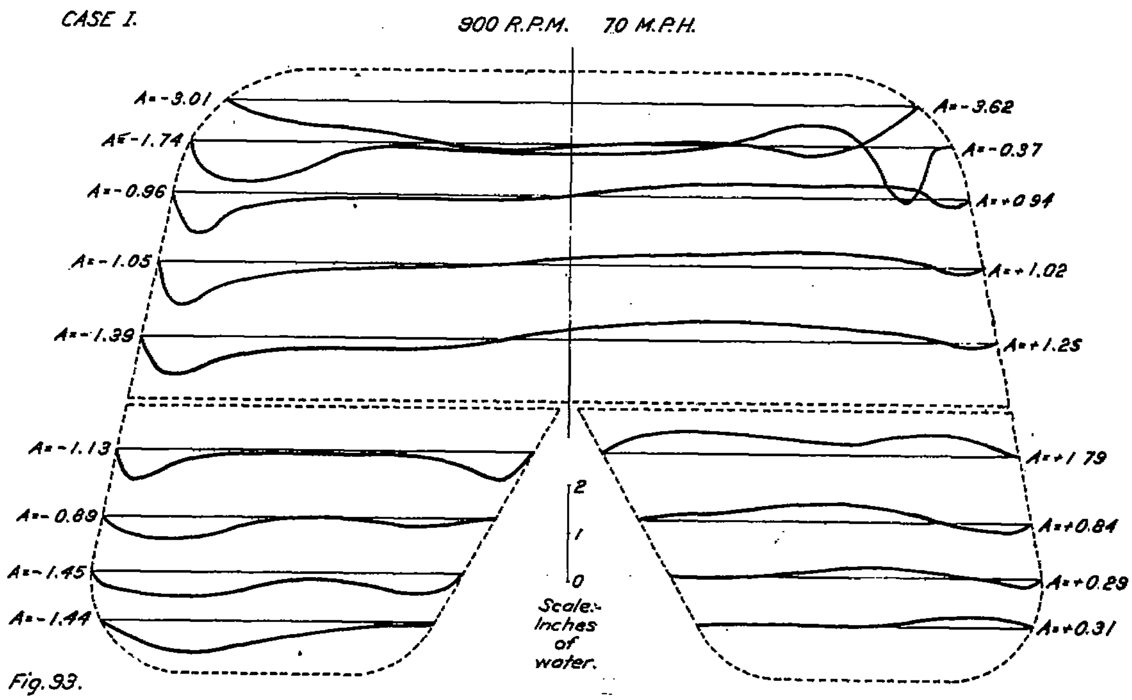

CASE I.
900 R.P.M. 70 M.P.H.
A=-3.01
A=-3.62
A=-1.74
A=-0.37
A=-0.96
A=+0.94
A=-1.05
A=+1.02
A=-1.39
A=+1.25
A=-1.13
A=+1.79
A=-0.89
A=+0.84
A=-1.45
A=+0.29
A=-1.44
A=+0.31
2
1
0
Scale:- Inches of water.

Fig. 93.

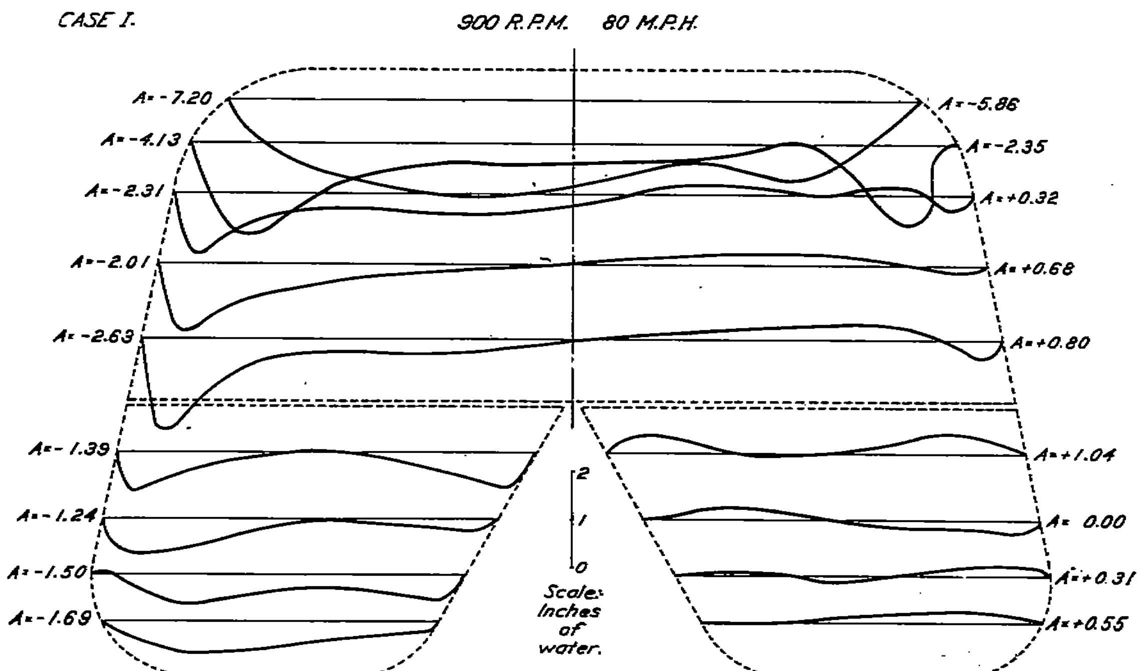

CASE I.
900 R.P.M. 80 M.P.H.
A=-7.20
A=-4.13
A=-2.31
A=-2.01
A=-2.63
A=-1.39
A=-1.24
A=-1.50
A=-1.69
A=-5.86
A=-2.35
A=+0.32
A=+0.68
A=+0.80
A=+1.04
A= 0.00
A=+0.31
A=+0.55
2
1
0
Scale:-
Inches
of
water.

Fig. 94.

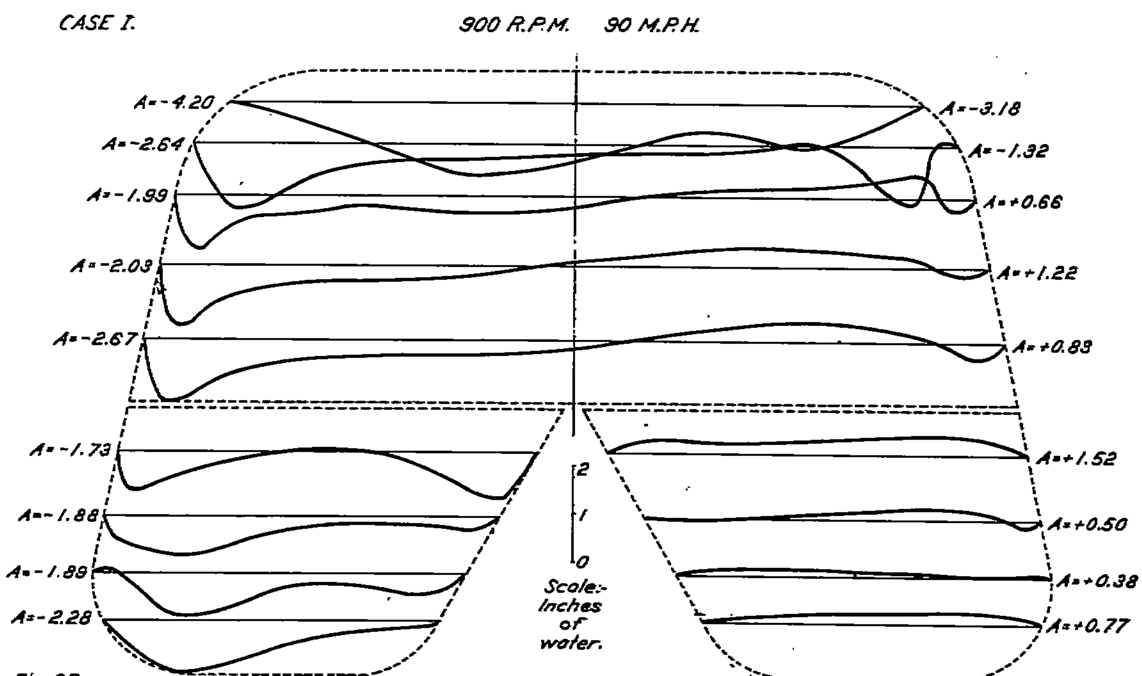
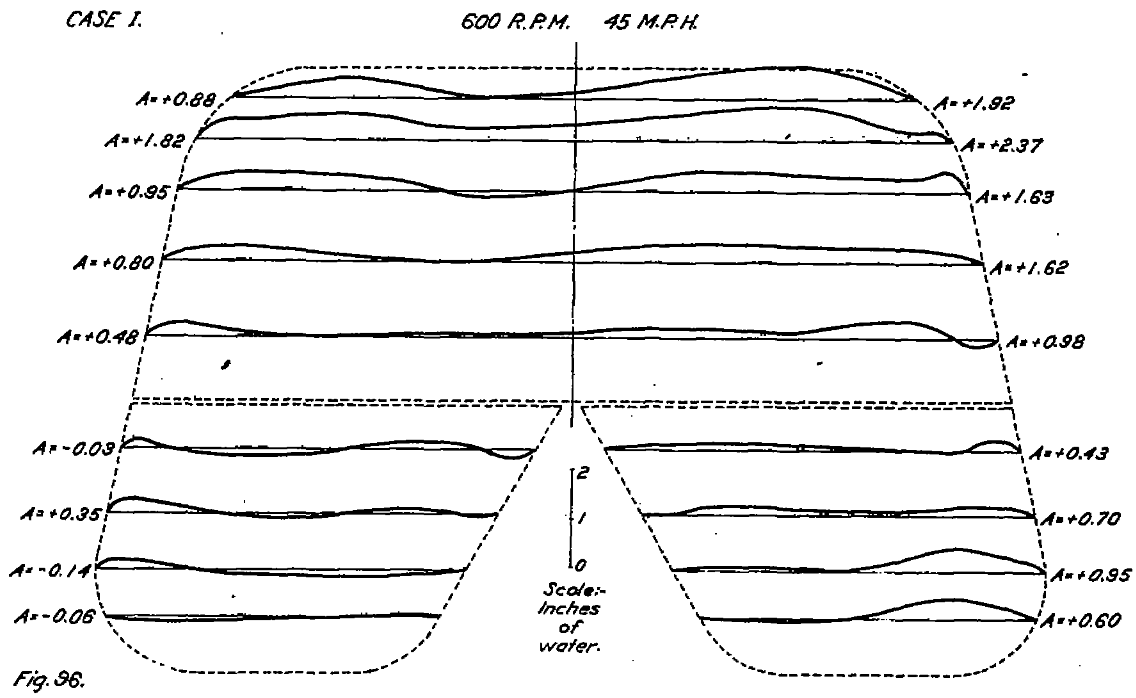
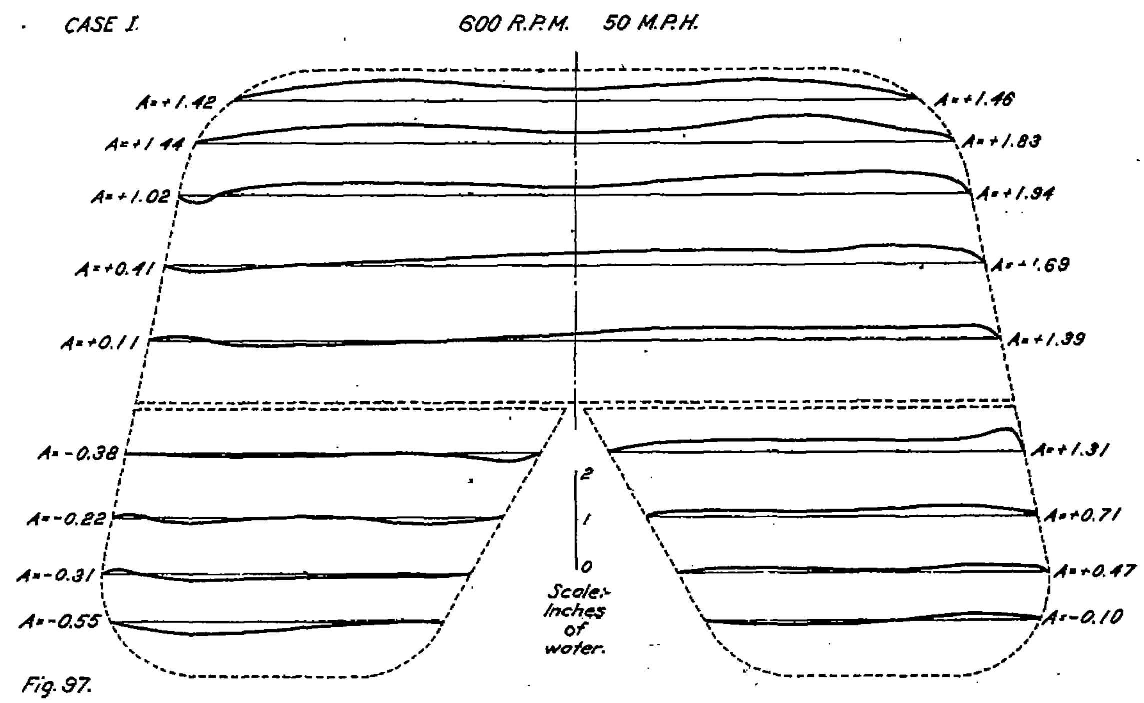

CASE I.
900 R.P.M. 90 M.P.H.
A=-4.20
A=-2.64
A=-1.99
A=-2.03
A=-2.67
A=-1.73
A=-1.88
A=-1.89
A=-2.28
A=-3.18
A=-1.32
A=+0.66
A=+1.22
A=+0.83
A=+1.52
A=+0.50
A=+0.38
A=+0.77
2
1
0
Scale:-
Inches
of
water.

Fig. 95.



CASE I.
600 R.P.M. 45 M.P.H.
A=+0.88
A=+1.82
A=+0.95
A=+0.80
A=+0.48
A=+1.92
A=+2.37
A=+1.63
A=+1.62
A=+0.98
A=-0.03
A=+0.35
A=-0.14
A=-0.06
A=+0.43
A=+0.70
A=+0.95
A=+0.60
2
1
0
Scale:-
Inches
of
water.

Fig. 96.



CASE I.
600 R.P.M. 50 M.P.H.
A=+1.42
A=+1.44
A=+1.02
A=+0.41
A=+0.11
A=+1.46
A=+1.83
A=+1.94
A=+1.69
A=+1.39
A=-0.38
A=-0.22
A=-0.31
A=-0.55
A=+1.31
A=+0.71
A=+0.47
A=-0.10
2
1
0
Scale:-
Inches
of
water.

Fig. 97.

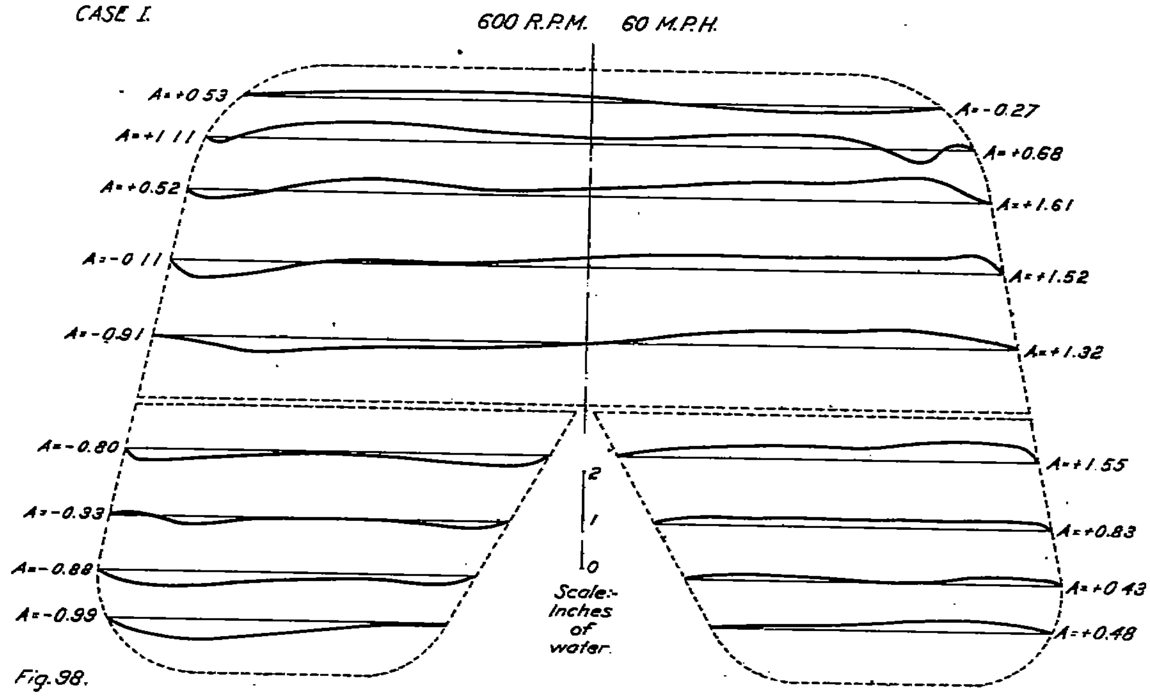

CASE I.
600 R.P.M. 60 M.P.H.
A=+0.53
A=+1.11
A=+0.52
A=-0.11
A=-0.91
A=-0.80
A=-0.33
A=-0.88
A=-0.99
A=-0.27
A=+0.68
A=+1.61
A=+1.52
A=+1.32
A=+1.55
A=+0.83
A=+0.43
A=+0.48
2
1
0
Scale:- Inches of water.

Fig. 98.

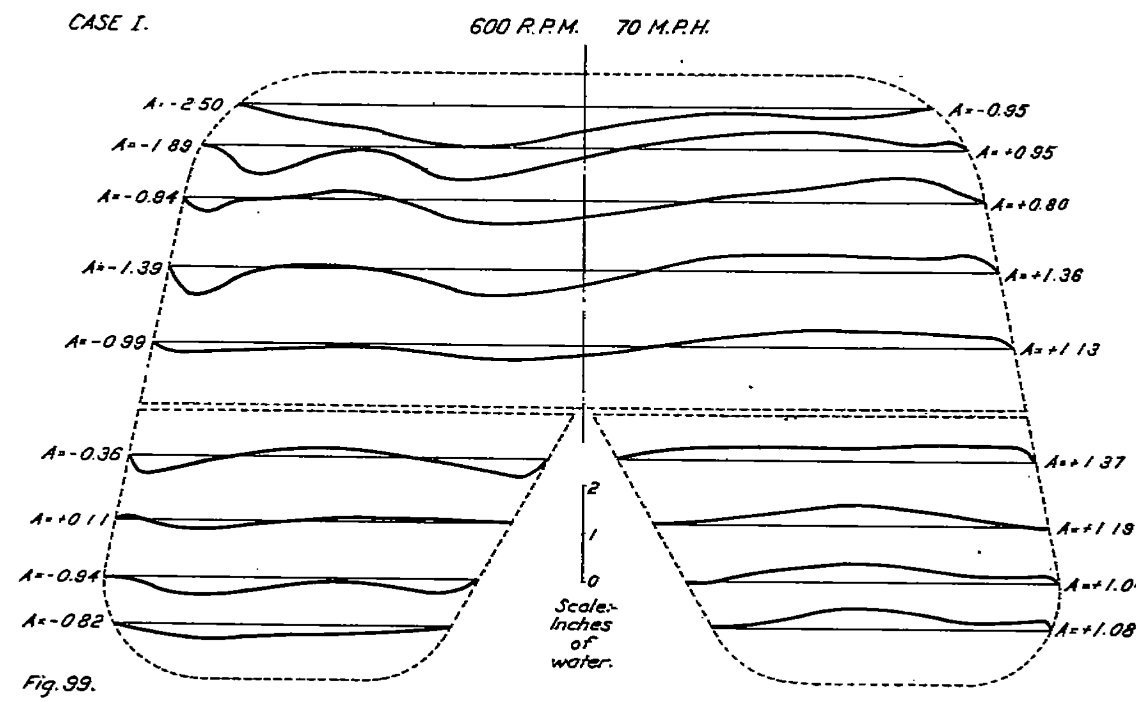

CASE I.
600 R.P.M. 70 M.P.H.
A=-2.50
A=-1.89
A=-0.84
A=-1.39
A=-0.99
A=-0.36
A=+0.11
A=-0.94
A=-0.82
A=-0.95
A=+0.95
A=+0.80
A=+1.36
A=+1.13
A=+1.37
A=+1.19
A=+1.04
A=+1.08
2
1
0
Scale:- Inches of water.

Fig. 99.

CASE I. 600 R.P.M. 80 M.P.H.

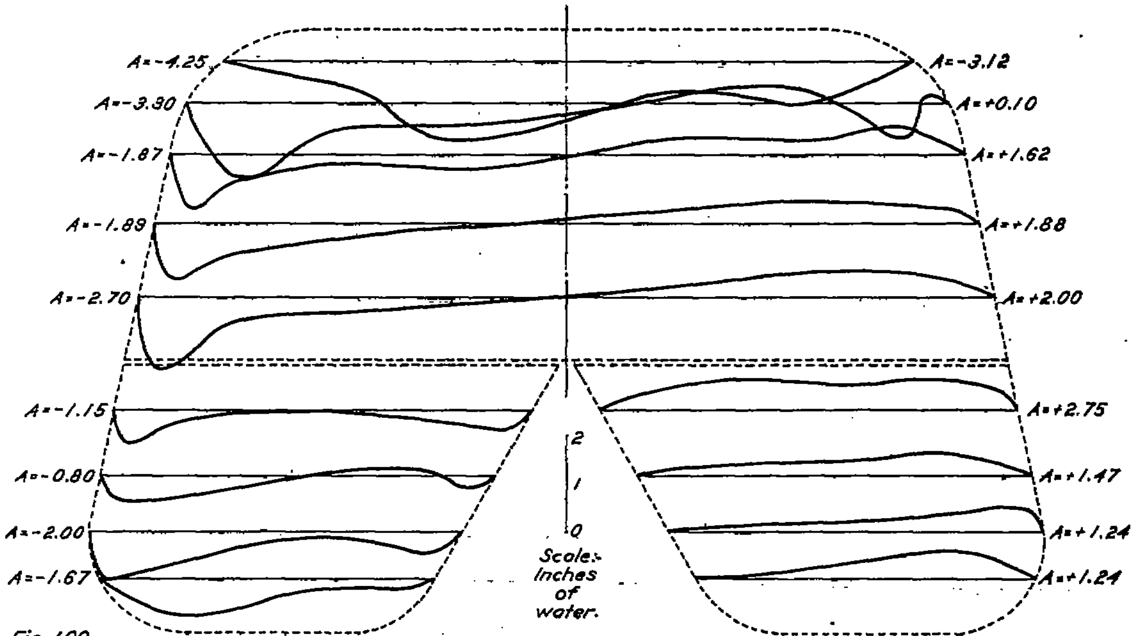


Fig. 100.

CASE I 600 R.P.M. 100 M.P.H.

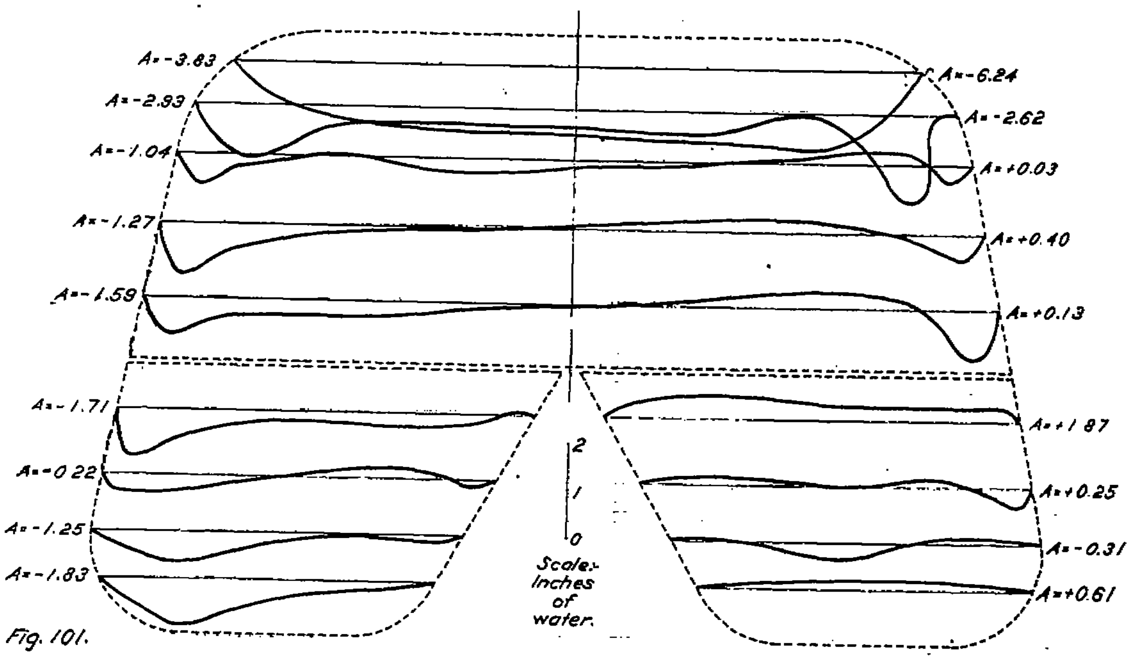


Fig. 101.

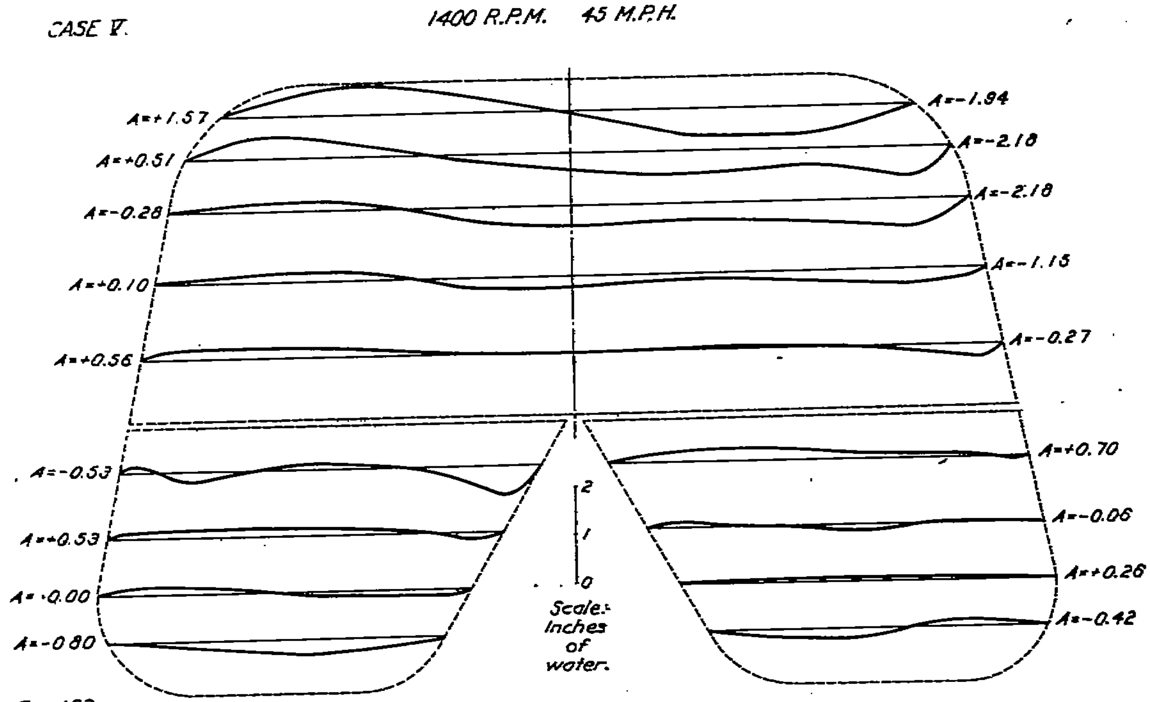


Fig. 102

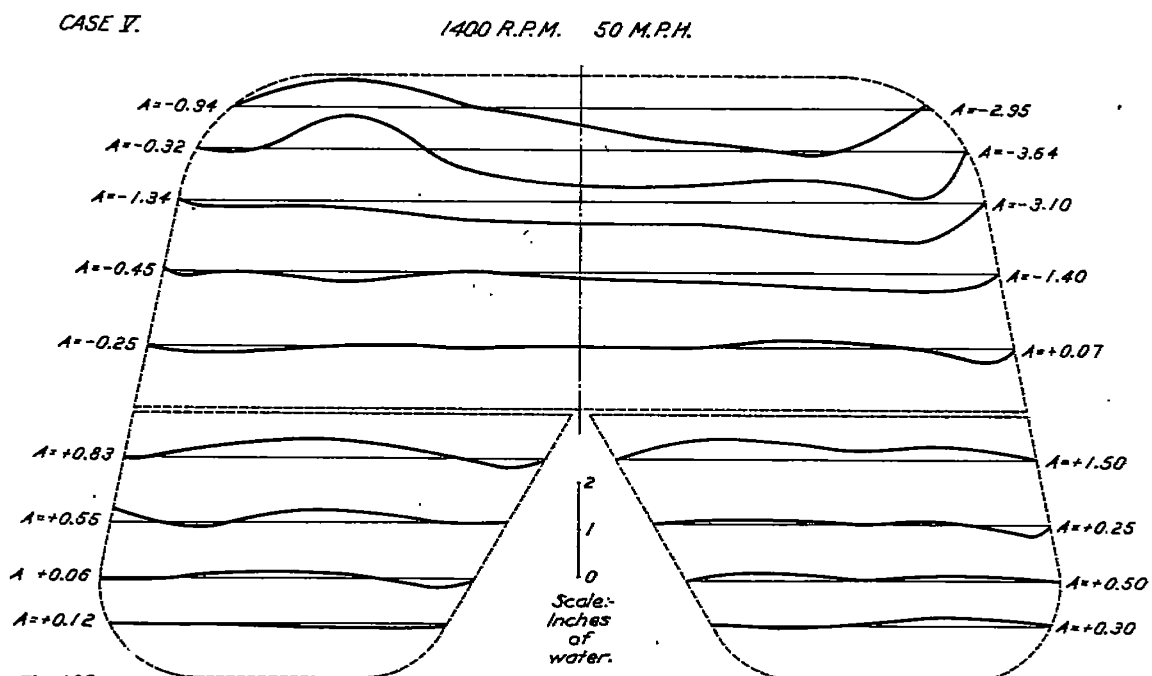


Fig. 103.

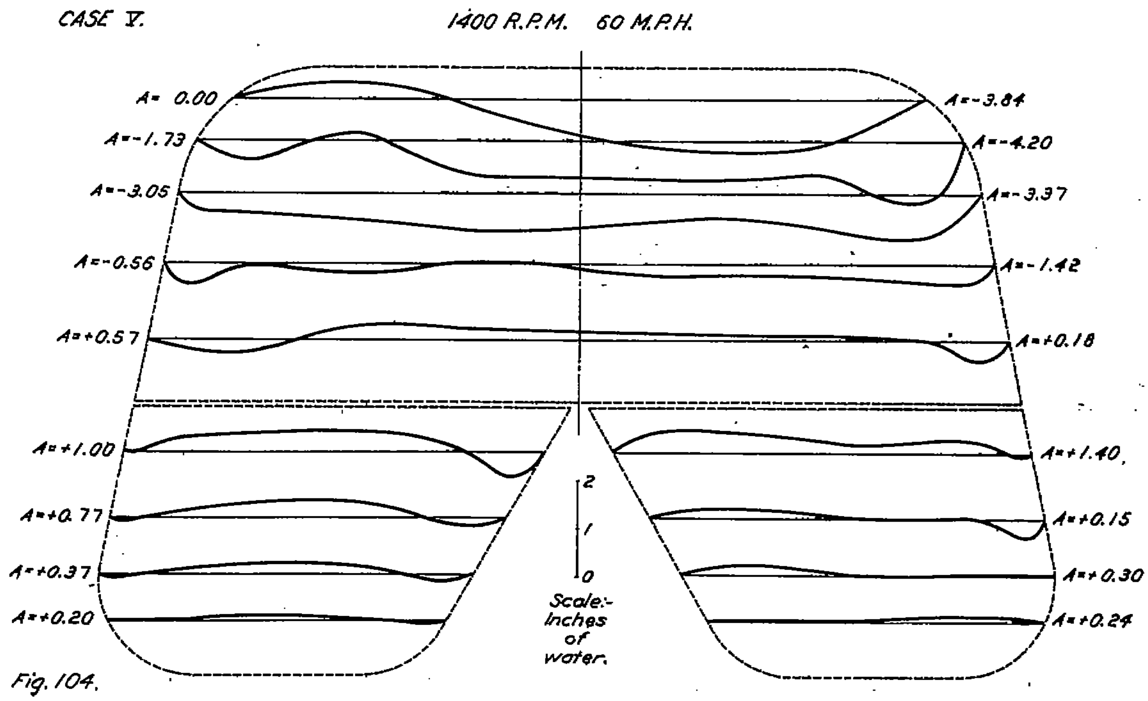


Fig. 104.

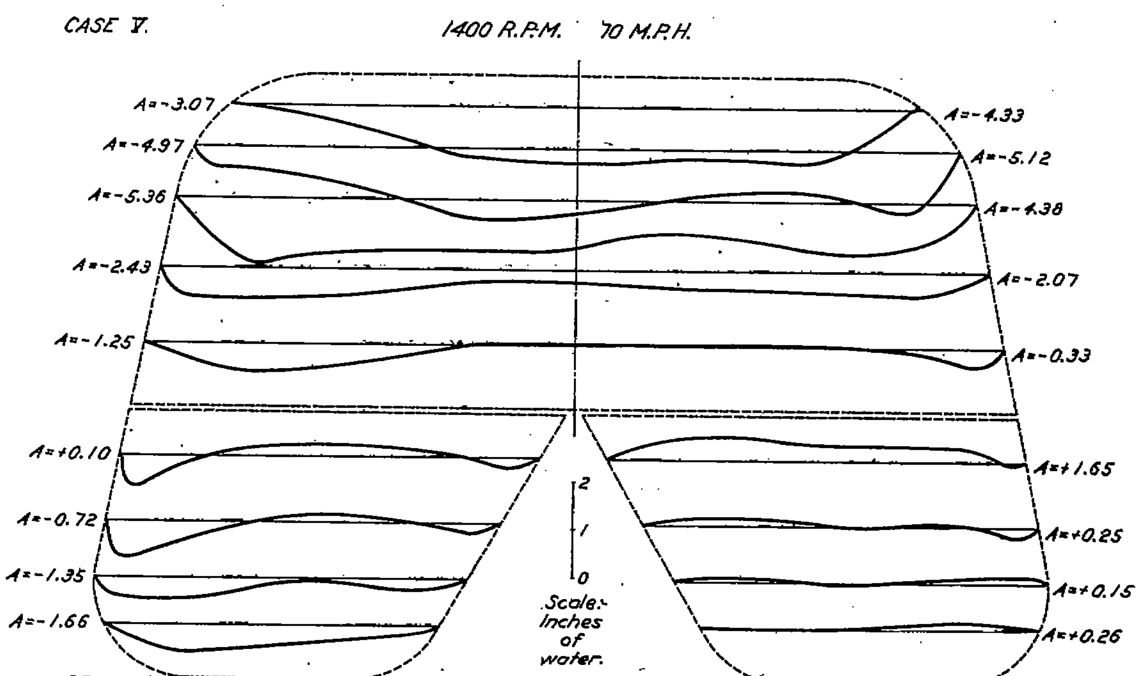


Fig. 105.

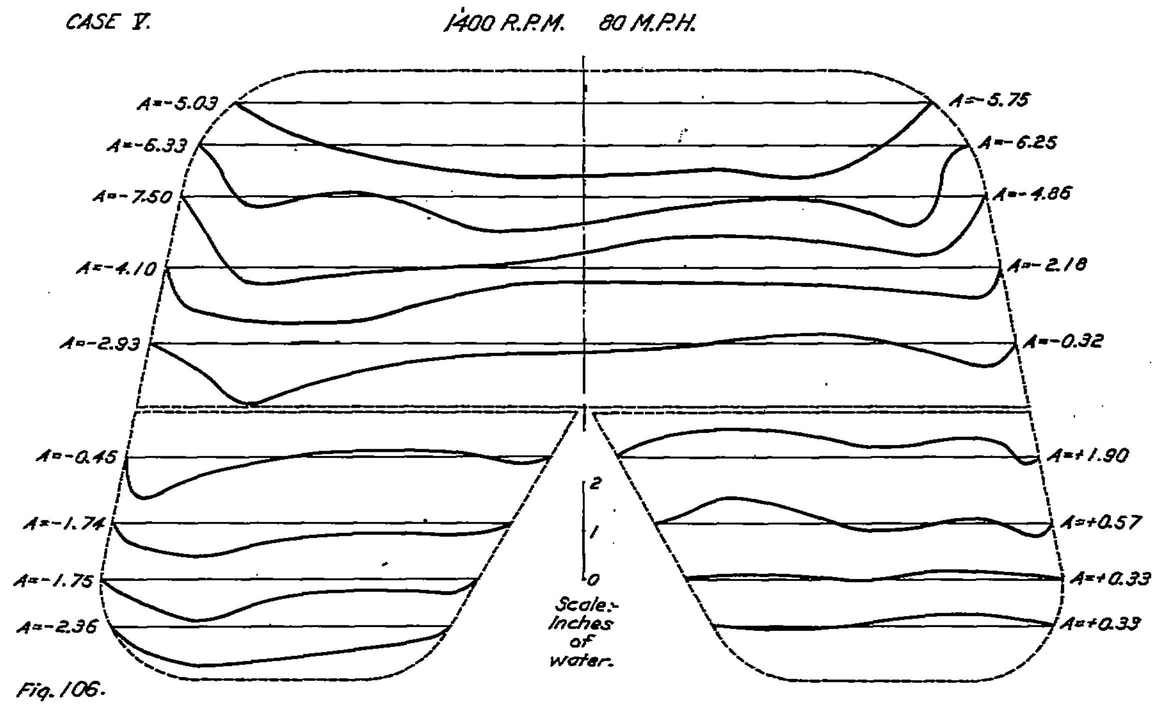


Fig. 106.

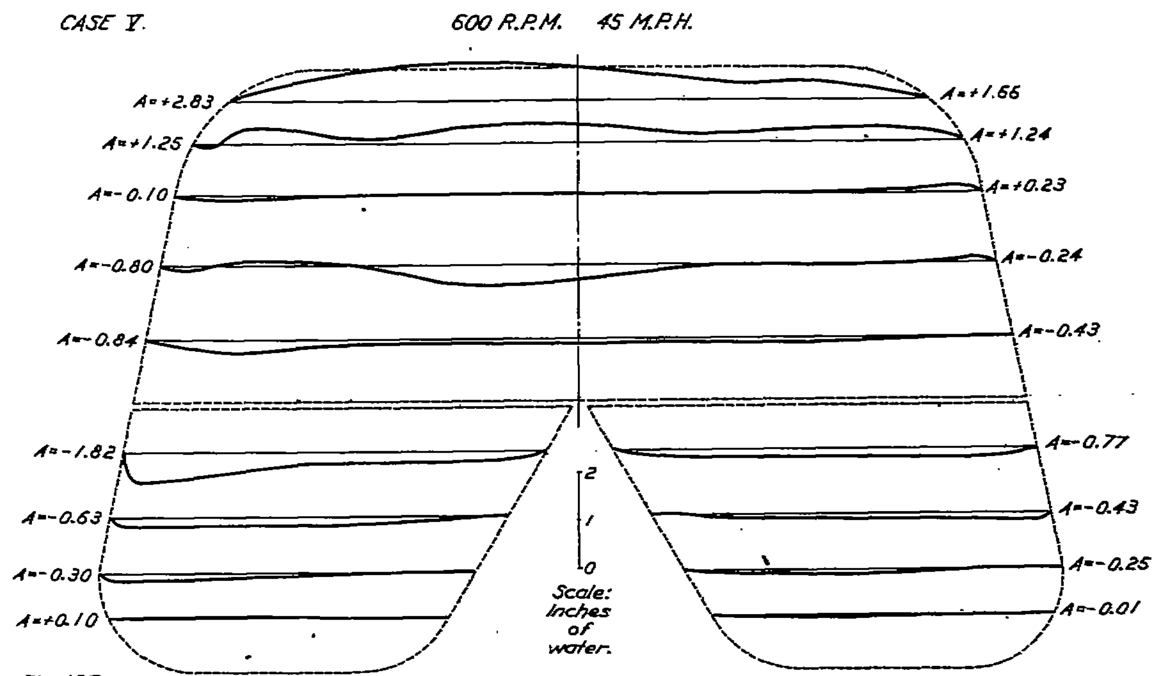


Fig. 107.

CASE V. 600 R.P.M. 50 M.P.H.

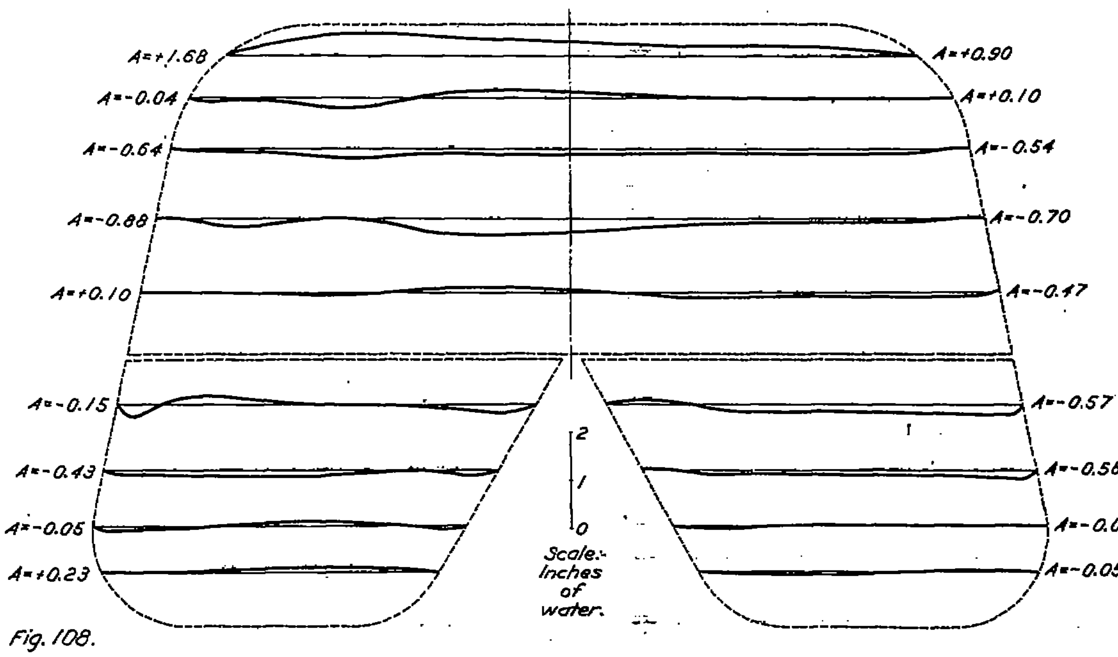


Fig. 108.

CASE V. 600 R.P.M. 60 M.P.H.

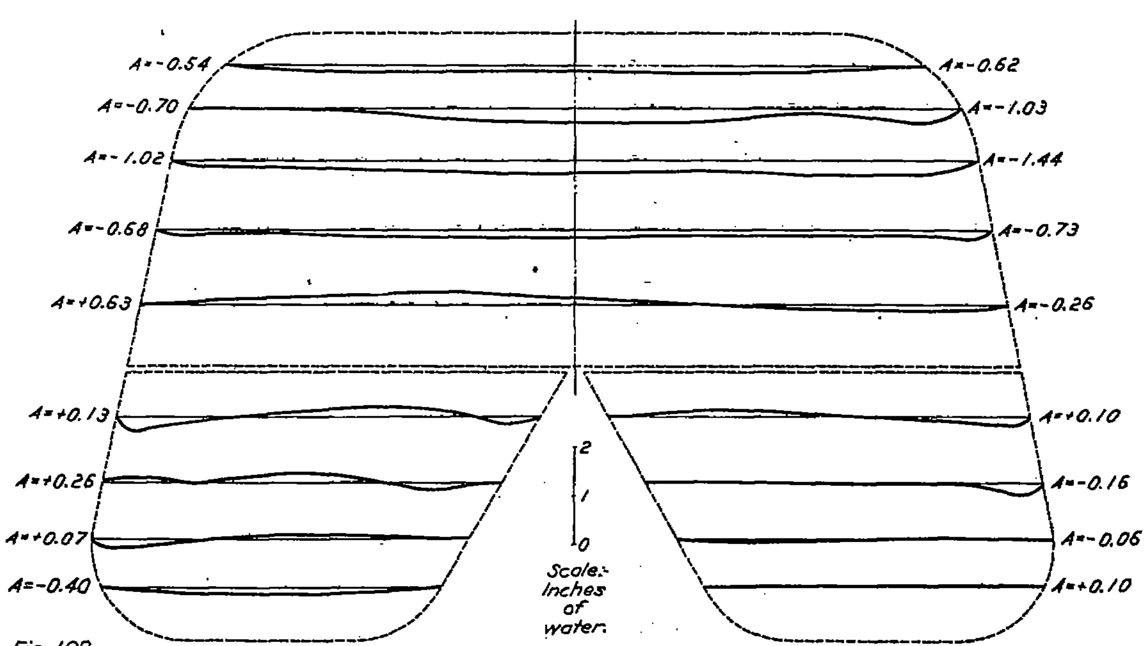


Fig. 109.

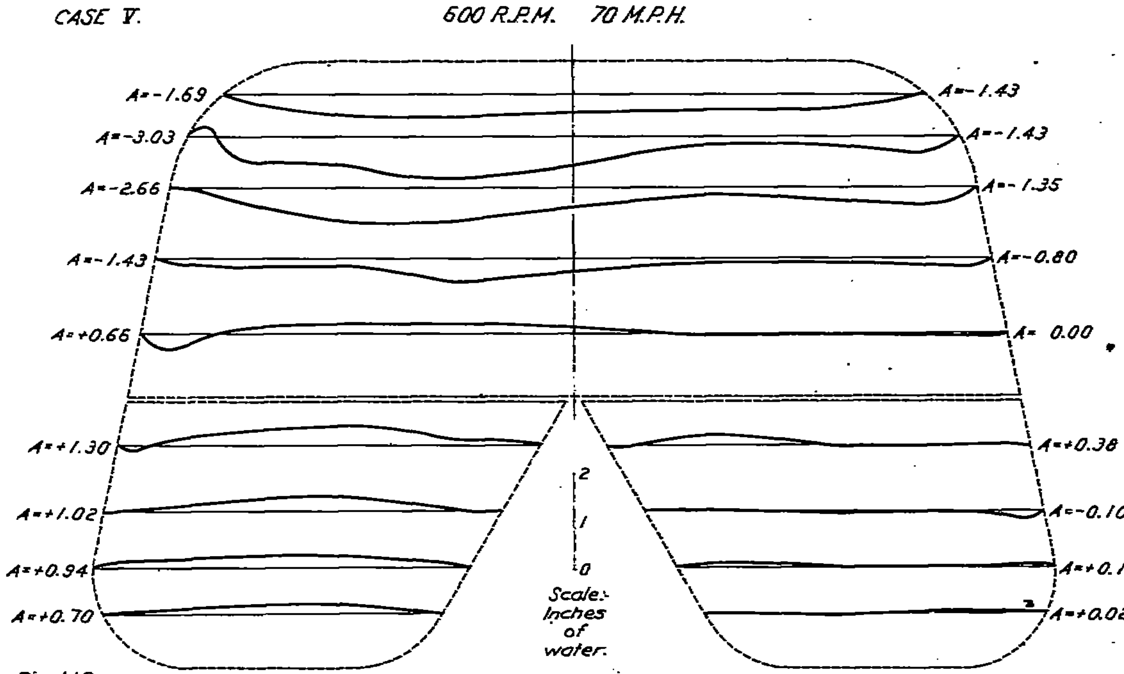


Fig. 110.

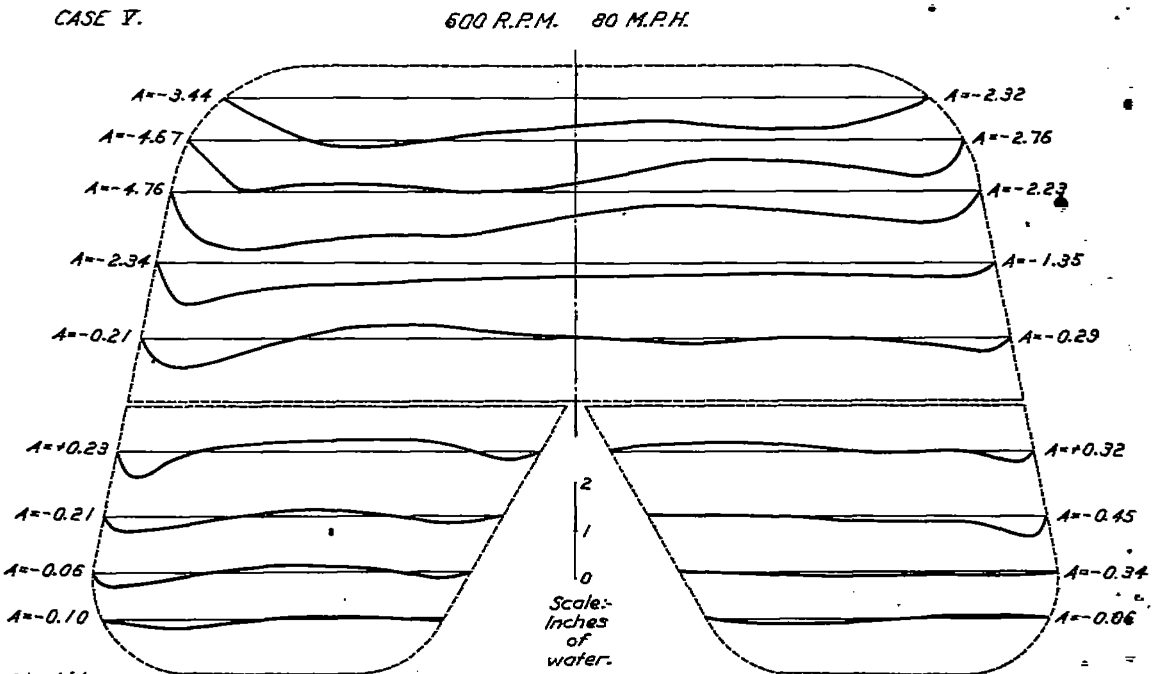


Fig. 111.

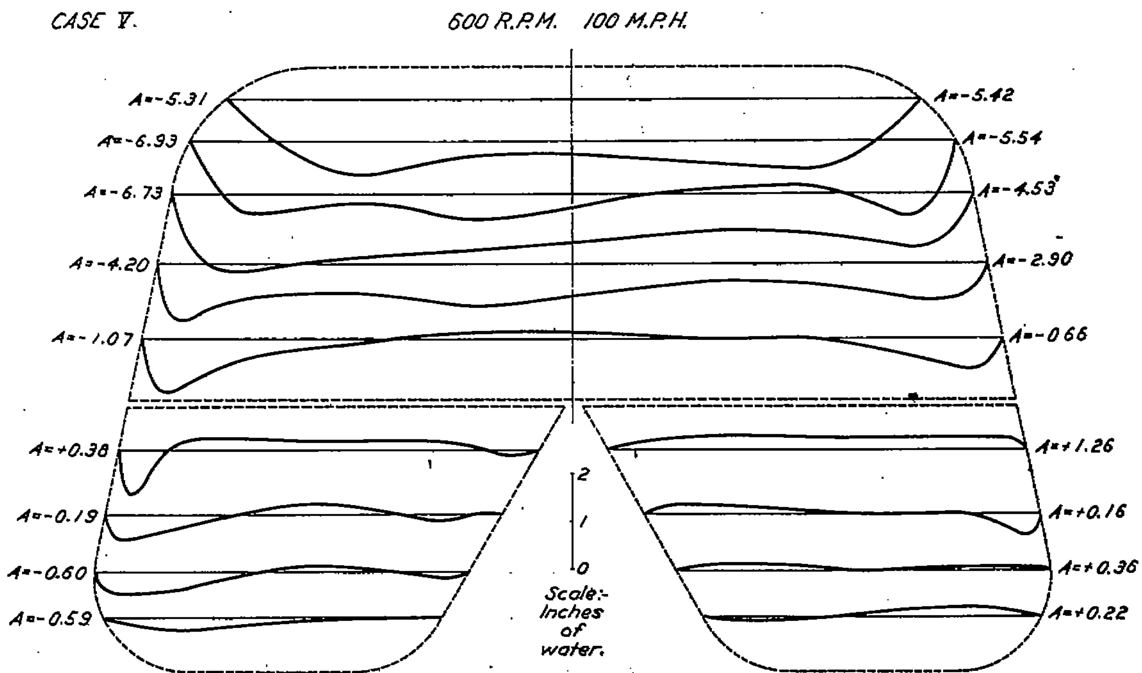


Fig. 112.

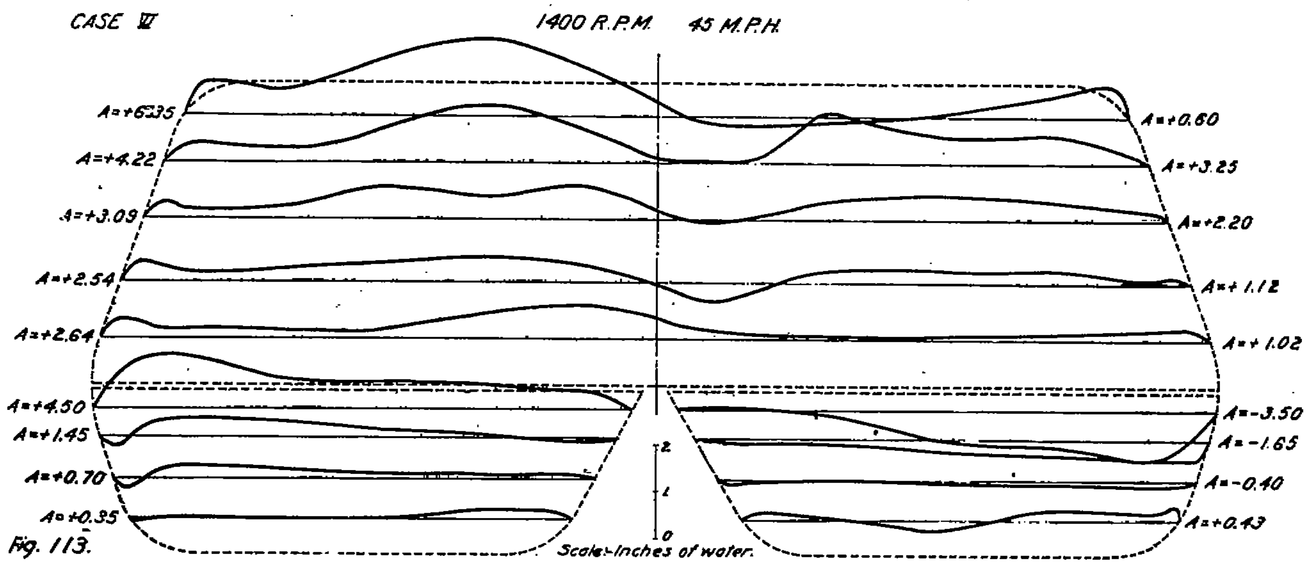


Fig. 113.

CASE VI. 1400 R.P.M. 50 M.P.H.

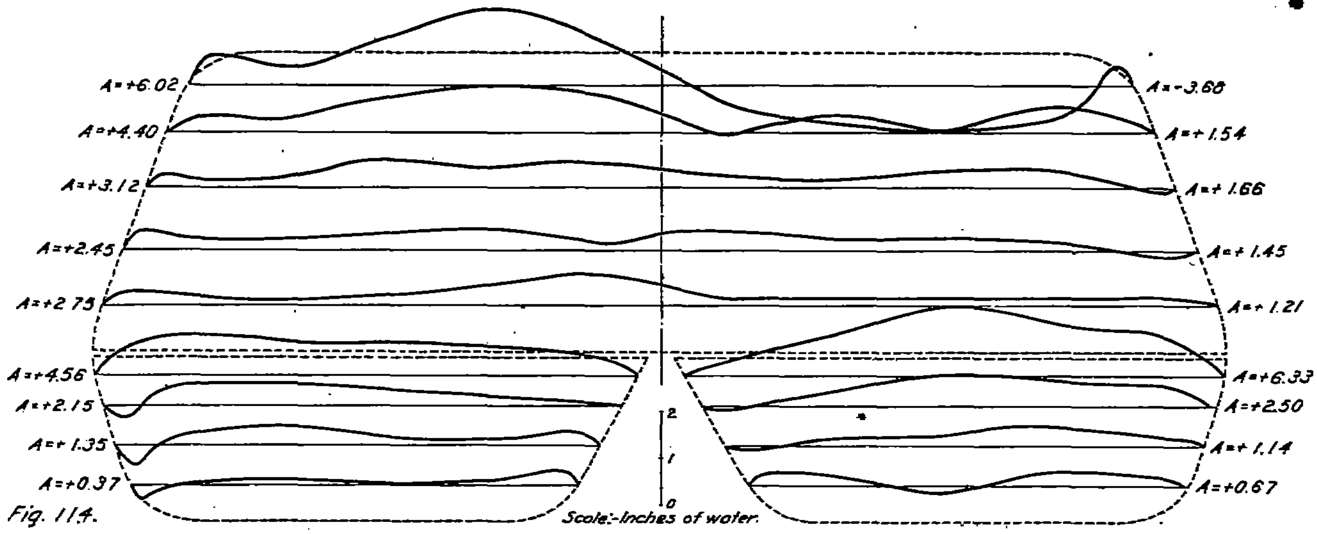


Fig. 114.

CASE VI 1400 R.P.M. 60 M.P.H.

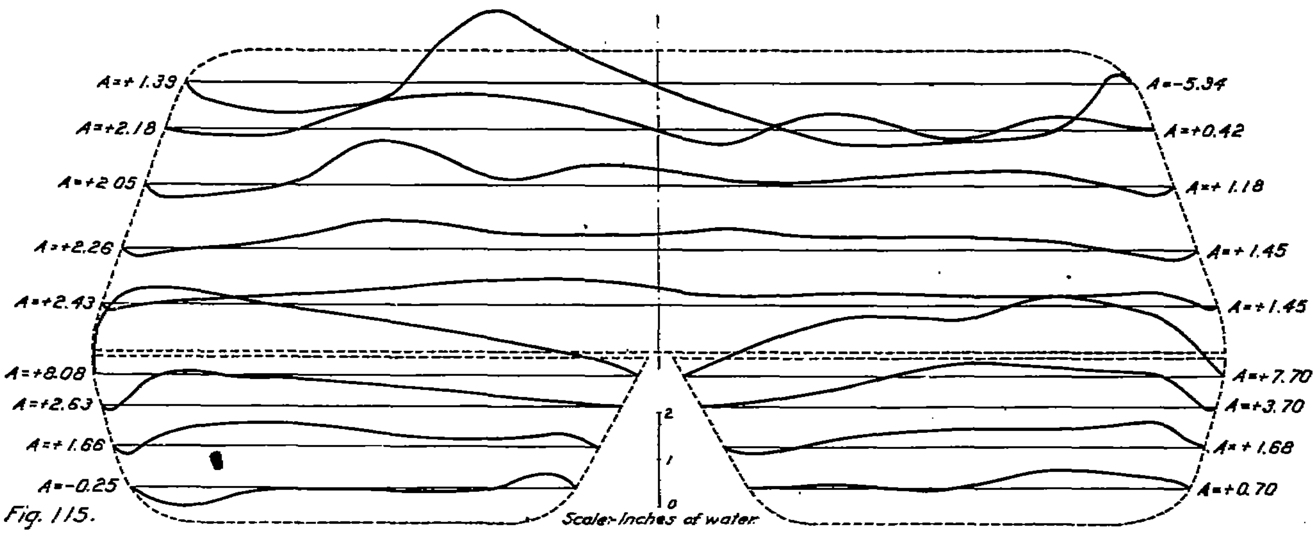


Fig. 115.

CASE VI. 1400 R.P.M. 70 M.P.H.

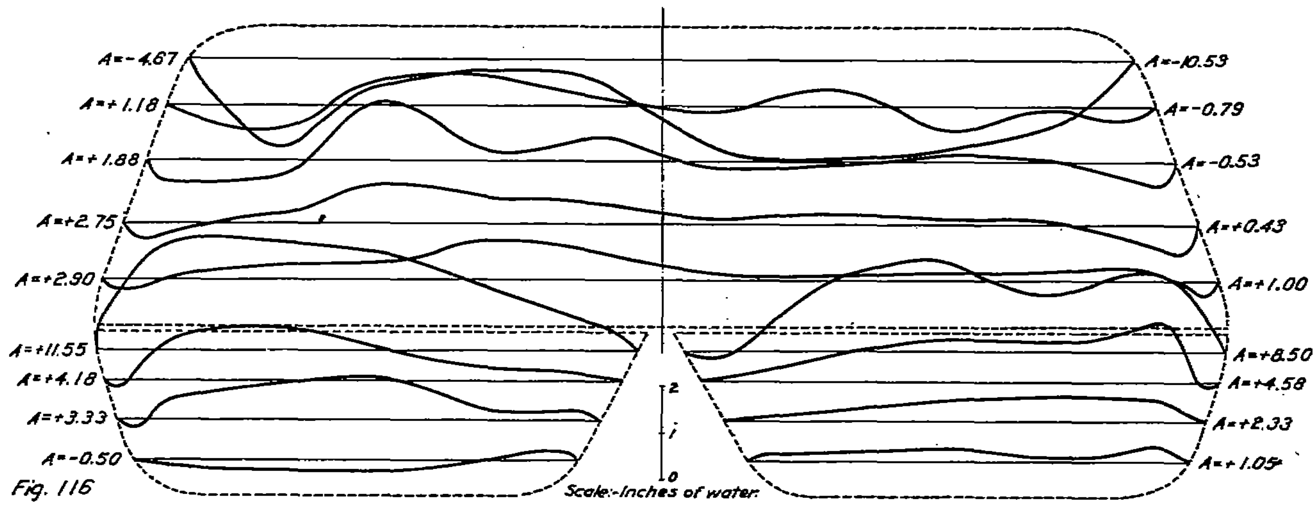


Fig. 116

CASE VI. 1400 R.P.M. 80 M.P.H.

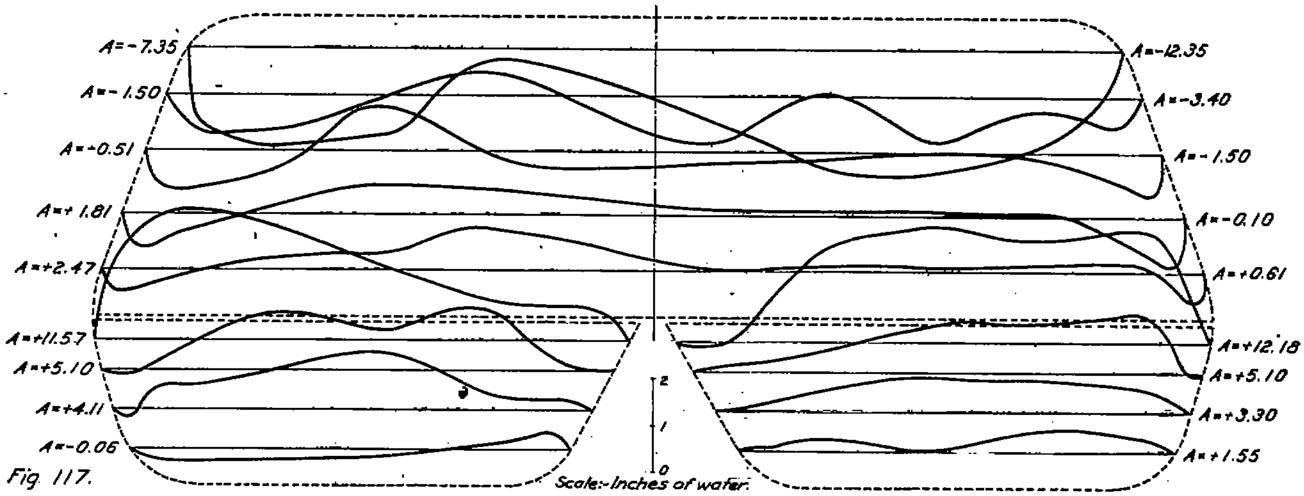


Fig. 117.

CASE VI 600 R.P.M. 50 M.P.H.

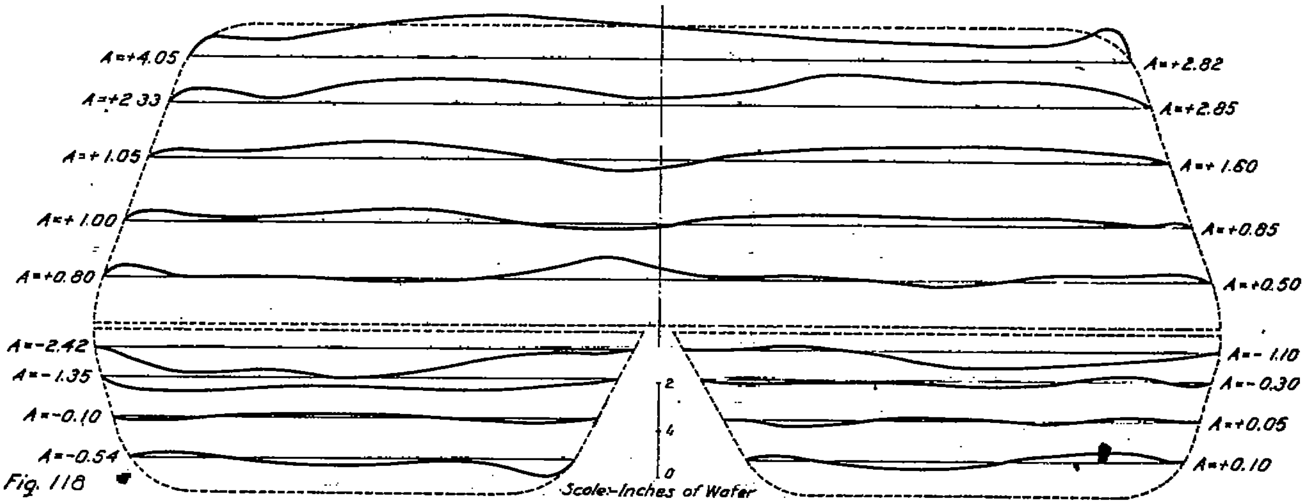


Fig. 118

CASE VI. 600 R.P.M. 60 M.P.H.

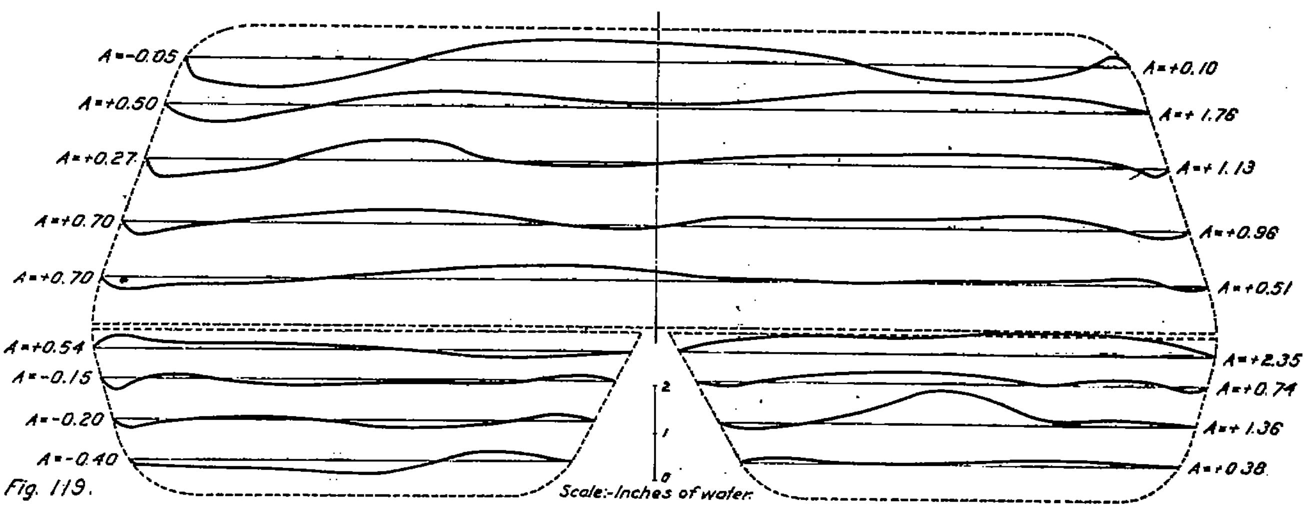


Fig. 119.

CASE VI. 600 R.P.M. 70 M.P.H.

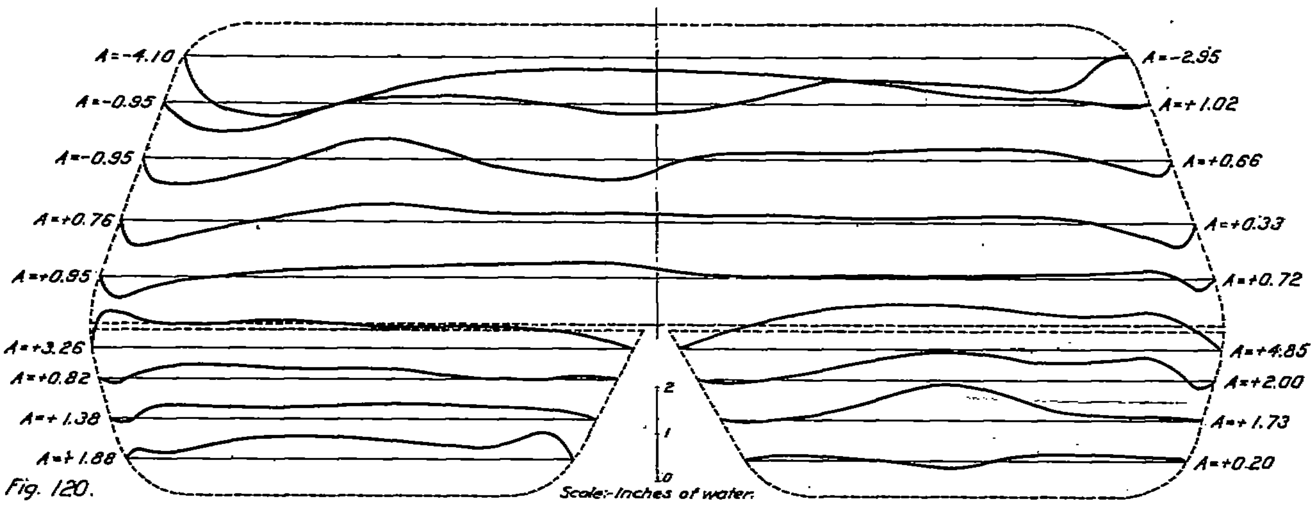


Fig. 120.

CASE VI. 600 R.P.M. 80 M.P.H.

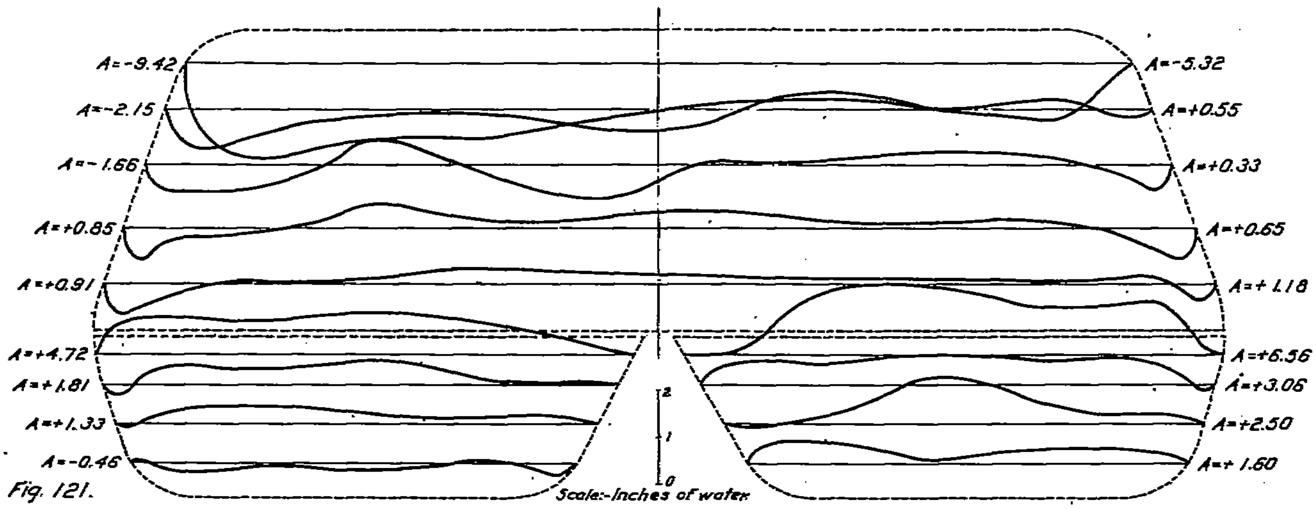


Fig. 121.

CASE VI. 600 R.P.M. 100 M.P.H.

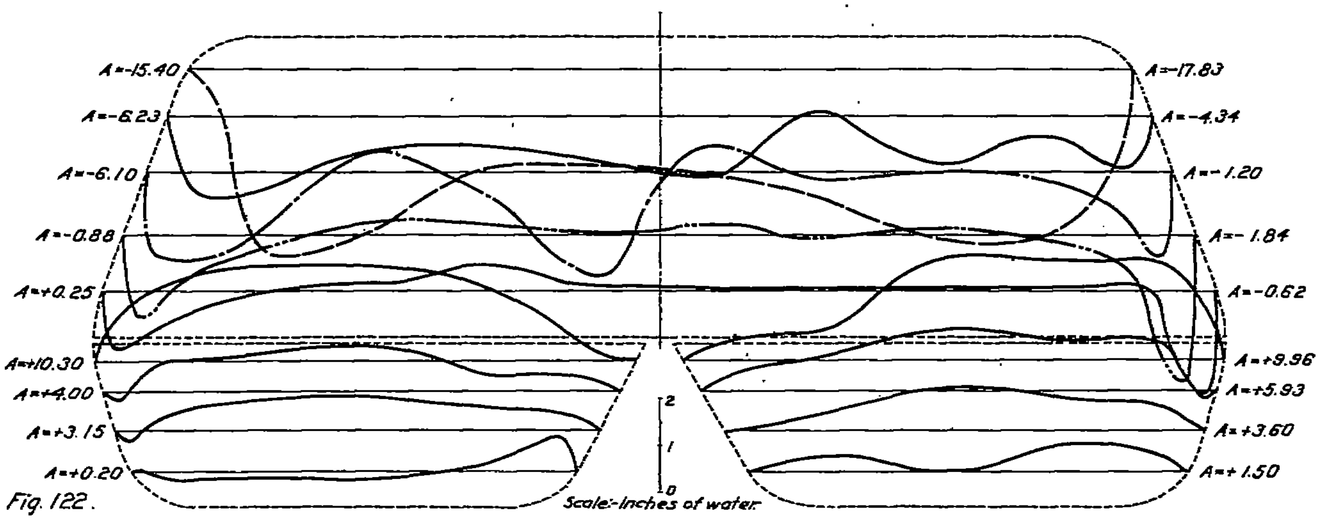
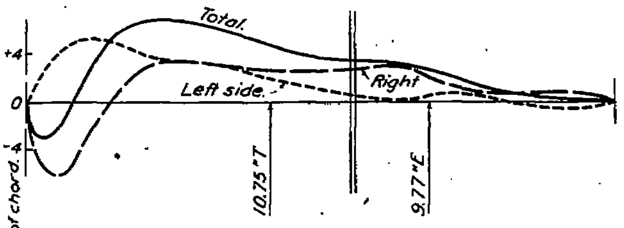


Fig. 122.

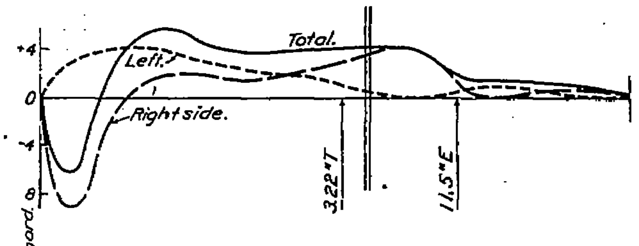
CASE I. 1400 R.P.M 45 M.P.H



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Up.	898.	32.5	1.081
Elevator	"	290	10.5	.474
Total	"		43.0	.824

Fig. 123. Elevator moment about hinge = 102.6 in. lbs.

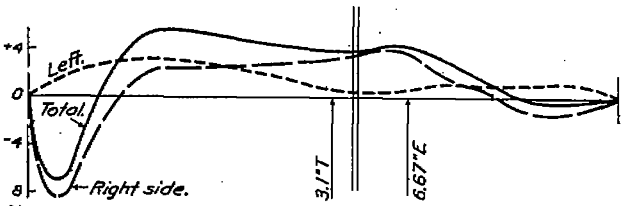
CASE I. 1400 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	604.	21.85	.728
Elevator.	"	366.	13.25	.596
Total.	"		35.10	.672

Fig. 124. Elevator moment about hinge = 152. in. lbs.

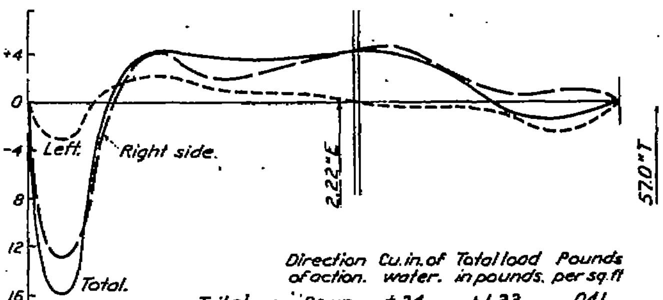
CASE I. 1400 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	568.	20.6	.685
Elevator.	"	304.	11.0	.495
Total.	"		31.6	.605

Fig. 125. Elevator moment about hinge = 73.5 in. lbs.

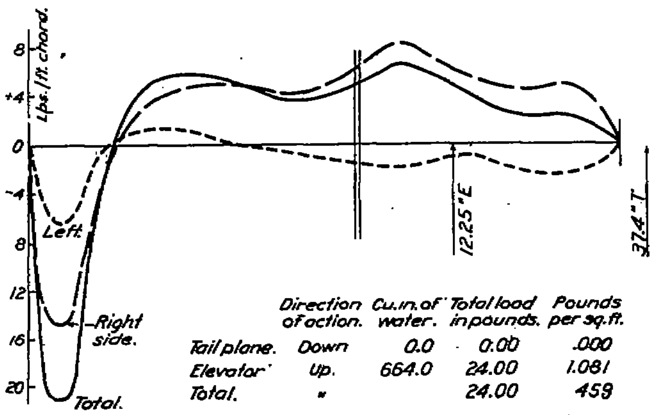
CASE I. 1400 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	+34.	+1.23	.041
Elevator.	Up.	184.	6.66	.300
Total	"		7.89	.151

Fig. 126. Elevator moment about hinge = -14.8 in. lbs.

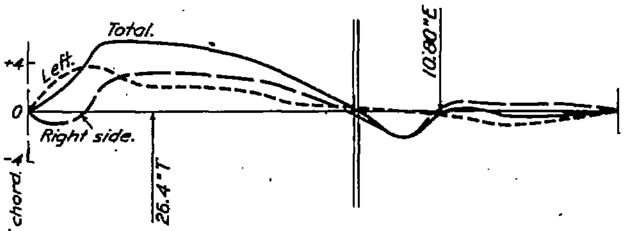
CASE I. 1400 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down	0.0	0.00	.000
Elevator	Up.	664.0	24.00	1.081
Total.	"		24.00	459

Fig. 127. Elevator moment about hinge = 294 in. lbs.

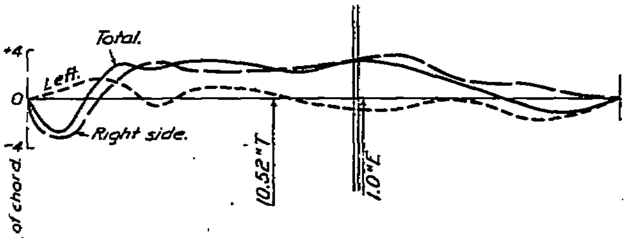
CASE I. 1200 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	808.	29.20	.974
Elevator.	"	88.	3.18	.144
Total.	"		32.38	.628

Fig. 128. Elevator moment about hinge = 34.4 in. lbs.

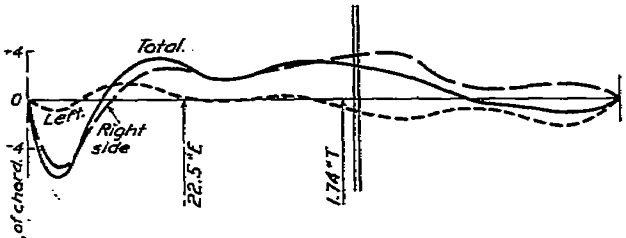
CASE I. 1200 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	380.	13.40	.446
Elevator.	"	136.	4.92	.222
Total.	"		18.32	.351

Fig. 129. Elevator moment about hinge = 4.92 in. lbs.

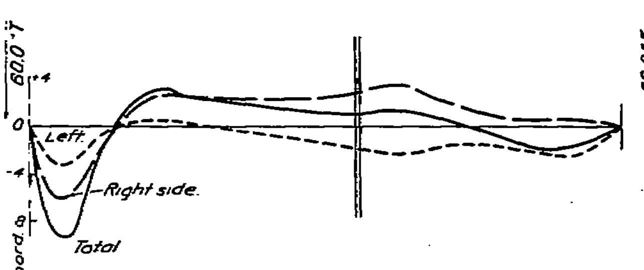
CASE I. 1200 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	260.	9.40	.314
Elevator.	"	54.	1.95	.088
Total	"		11.35	.217

Fig. 130. Elevator moment about hinge = -43.9 in. lbs.

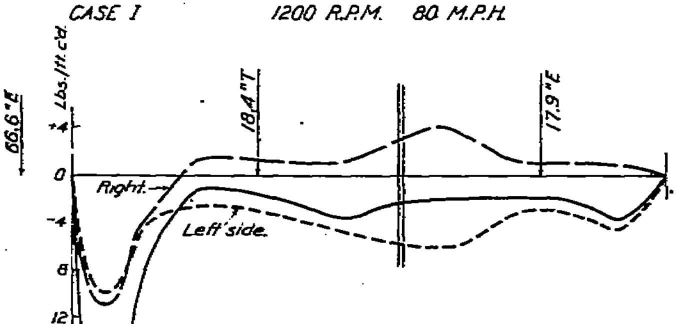
CASE I 1200 R.P.M 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down	-28.	-1.01	.034
Elevator	"	-40.	-1.45	.065
Total	"		-2.46	.047

Fig. 131. Elevator moment about hinge = -96.7 in. lbs.

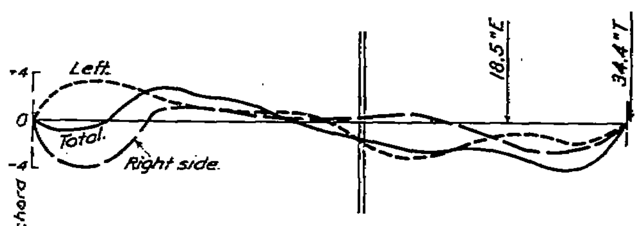
CASE I 1200 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Down	-1188.	-43.0	1.430
Elevator	"	-380.	-13.8	.620
Total	"		-56.8	1.087

Fig. 132. Elevator moment about hinge = -[illegible]47.0 in. lbs.

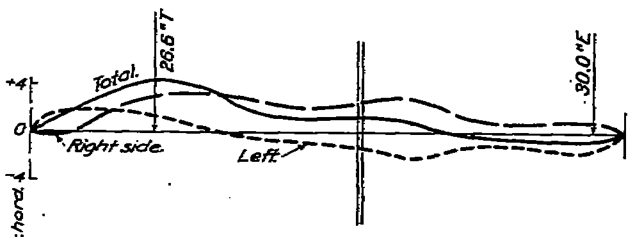
CASE I. 900 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	122.	4.42	.147
Elevator.	Down.	-462.	-16.70	.753
Total.	"		-12.28	.235

Fig. 133. Elevator moment about hinge = -309.0 in. lbs.

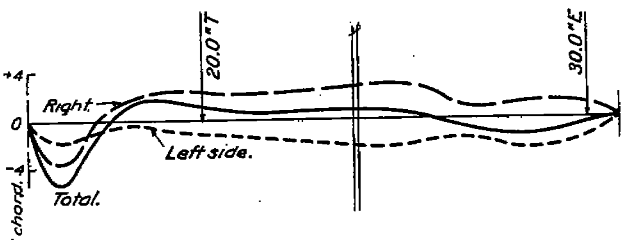
CASE I. 900 R.P.M. 50 M.P.H



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	516.	18.710	.624
Elevator.	Down.	-20.	- .725	.0326
Total.	Up.		17.985	.344

Fig. 134. Elevator moment about hinge = -2.175 in. lbs.

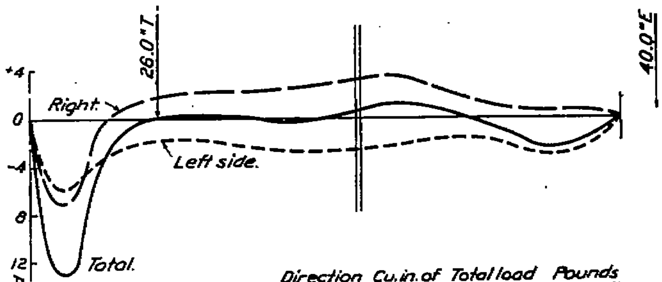
CASE I. 900 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Down.	-28.	-1.01	.0337
Elevator.	"	-68.	-2.46	.111
Total.	"		-3.47	.0665

Fig. 135. Elevator moment about hinge = -73.8 in. lbs.

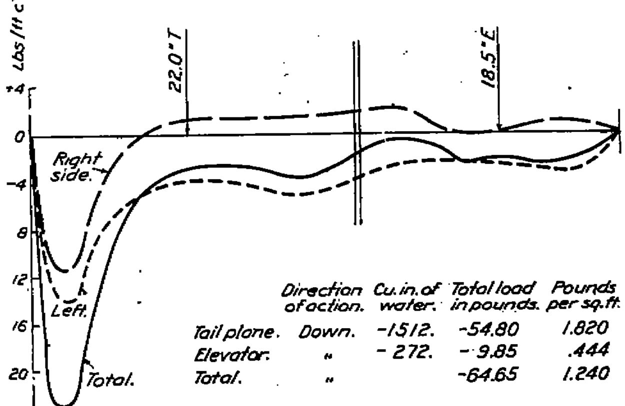
CASE I 900 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-488.	-17.70	.590
Elevator.	"	-82.	-2.97	.134
Total.	"		-20.67	.396

Fig. 136. Elevator moment about hinge = -119. in. lbs.

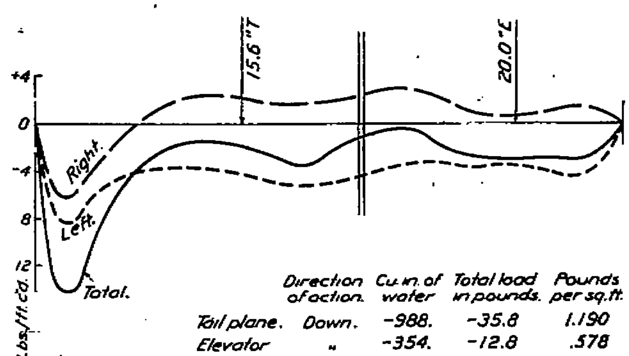
CASE I. 900 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1512.	-54.80	1.820
Elevator.	"	-272.	-9.85	.444
Total.	"		-64.65	1.240

Fig. 137. Elevator moment about hinge = -182. in. lbs.

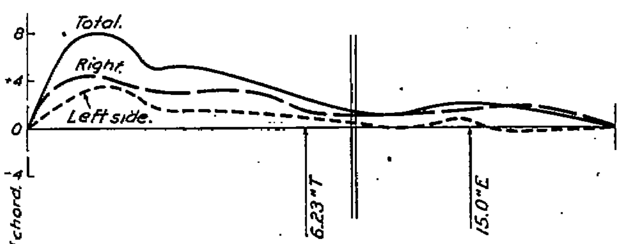
CASE I. 900 R.P.M. 90 M.P.H



	Direction of action.	Cu. in. of water	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-988.	-35.8	1.190
Elevator	"	-354.	-12.8	.578
Total.	"		-48.6	.930

Fig. 138. Elevator moment about hinge = -256. in. lbs.

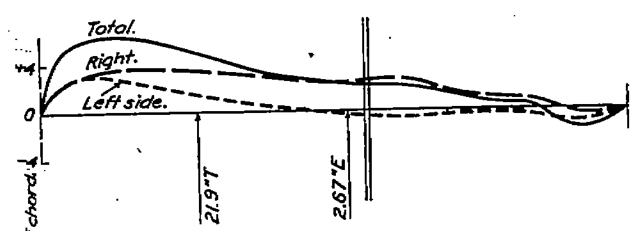
CASE I 600 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Up.	996.	36.10	1.207
Elevator.	"	244.	8.84	.398
Total.	"		44.94	.860

Fig. 139. Elevator moment about hinge = 132.6 in. lbs.

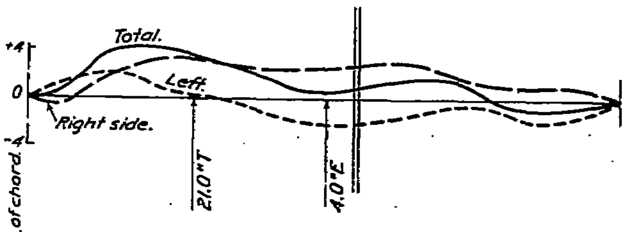
CASE I. 600 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	964.	34.90	1.162
Elevator.	"	100.	3.62	.163
Total.	"		38.52	.737

Fig. 140. Elevator moment about hinge = -9.66 in. lbs.

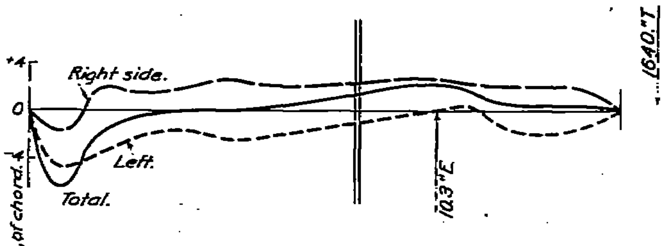
CASE I. 600 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	504.	18.23	.607
Elevator.	"	68.	2.46	.111
Total.	"		20.69	.396

Fig. 141. Elevator moment about hinge = -9.85 in. lbs.

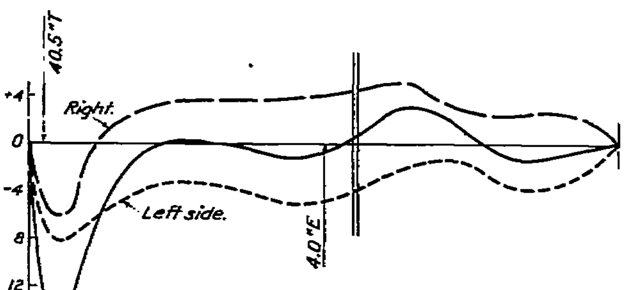
CASE I. 600 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-204.	-7.39	.246
Elevator.	Up.	210.	7.60	.342
Total.	"		.21	.0040

Fig. 142. Elevator moment about hinge = 78.3 in. lbs.

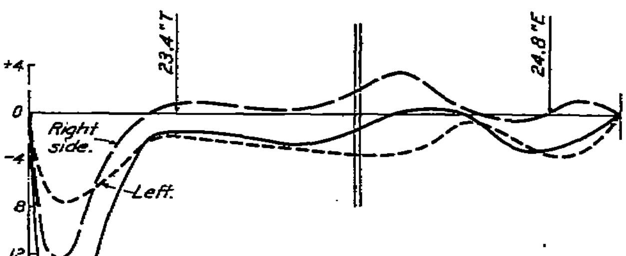
CASE I. 600 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-658.	-23.80	.794
Elevator.	Up.	102.	3.70	.166
Total.	"		-20.10	.576

Fig. 143. Elevator moment about hinge = -14.8 in. lbs.

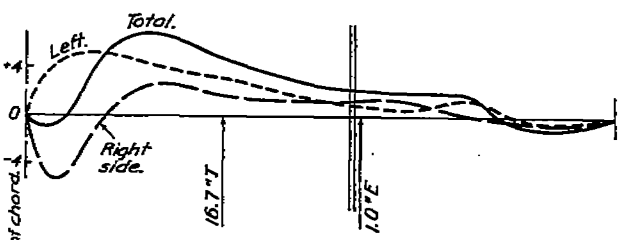
CASE I. 600 R.P.M. 100 M.P.H.



	Direction of action	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1216.	-44.0	1.466
Elevator.	"	- 184.	- 6.66	.300
Total.	"		-50.66	.971

Fig. 144. Elevator moment about hinge = -165.4 in. lbs.

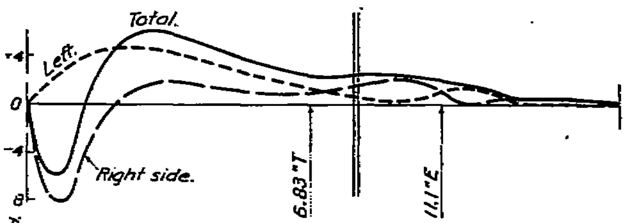
CASE II. 1400 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	854.	30.90	1.029
Elevator.	"	136.	4.92	.0221
Total.	"		35.82	.686

Fig. 145. Elevator moment about hinge = 4.92 in. lbs.

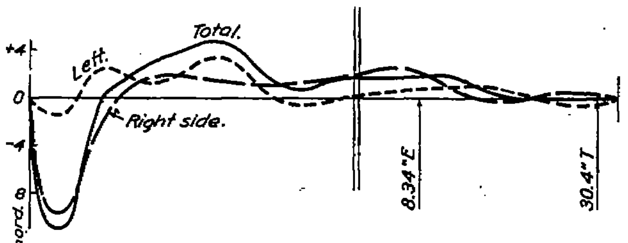
CASE II. 1400 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Up.	590.	21.40	.712
Elevator.	"	244.	8.82	.397
Total.	"		30.22	.579

Fig. 146. Elevator moment about hinge = 98. in. lbs.

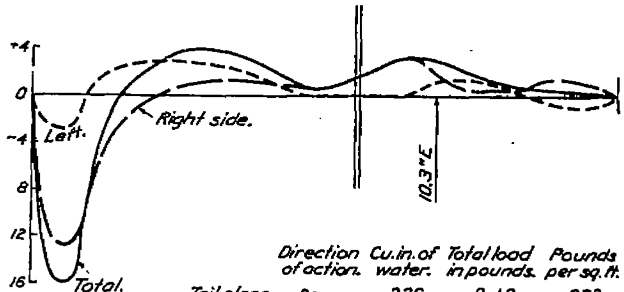
CASE II. 1400 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	90.	3.26	.109
Elevator.	〃	162.	5.86	.264
Total.	〃		9.12	.175

Fig. 147. Elevator moment about hinge = 48.9 in. lbs.

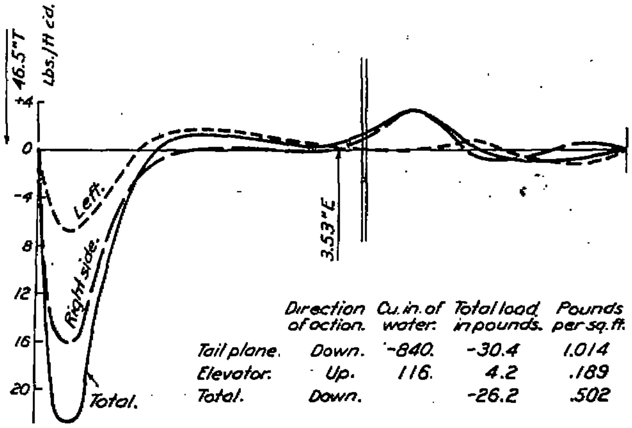
CASE II. 1400 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-226.	-8.19	.273
Elevator.	Up.	278.	10.05	.454
Total.	〃		1.86	.0356

Fig. 148. Elevator moment about hinge = 103.6 in. lbs.

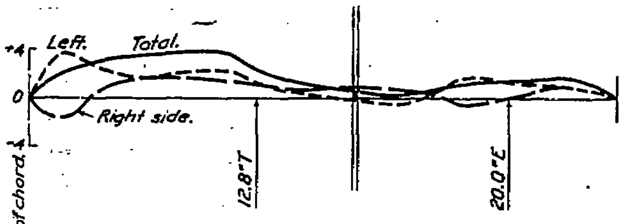
CASE II. 1400 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-840.	-30.4	1.014
Elevator.	Up.	116.	4.2	.189
Total.	Down.		-26.2	.502

Fig. 149. Elevator moment about hinge = -14.8 in. lbs.

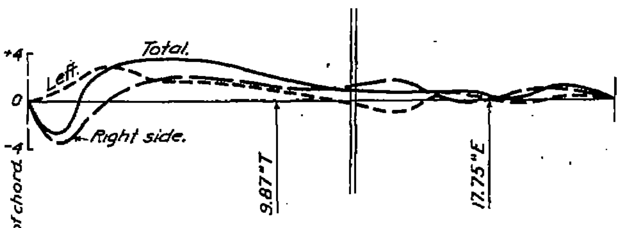
CASE II. 1200 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	556.	20.15	.671
Elevator.	〃	190.	6.88	.310
Total.	〃		27.03	.517

Fig. 150. Elevator moment about hinge = 137.8 in. lbs.

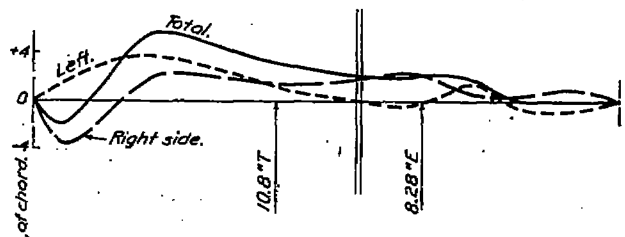
CASE II. 1200 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	372.	13.50	.450
Elevator.	〃	122.	4.42	.199
Total.	〃		17.92	.344

Fig. 151. Elevator moment about hinge = 78.6 in. lbs.

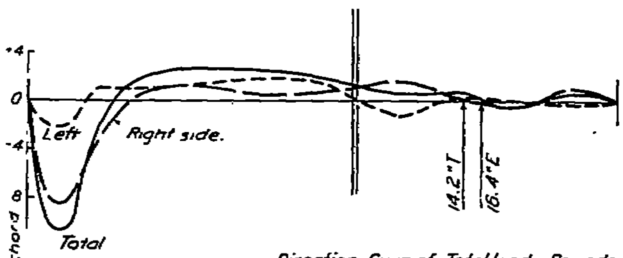
CASE II. 1200 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	644.	23.3	.725
Elevator.	〃	196.	7.1	.32
Total.	〃		30.4	.582

Fig. 152. Elevator moment about hinge = 58.8 in. lbs.

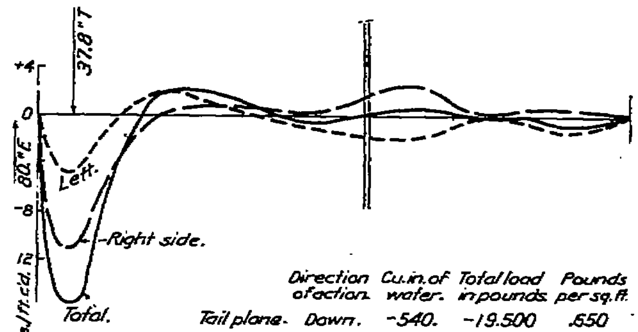
CASE II 1200 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Down.	-6.	-.218	.0072
Elevator	Up	74.	2.680	.121
Total	"		2.462	.471

Fig 153. Elevator moment about hinge = 40.4 in. lbs.

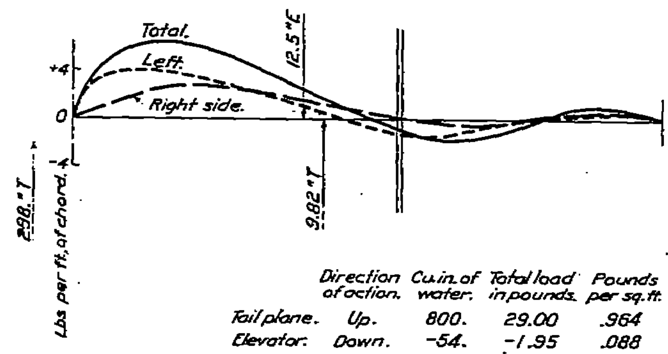
CASE II. 1200 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-540.	-19.500	.650
Elevator.	Up.	4.	.145	.0065
Total.	Down.		-19.355	.370

Fig. 154. Elevator moment about hinge = 11.6 in. lbs.

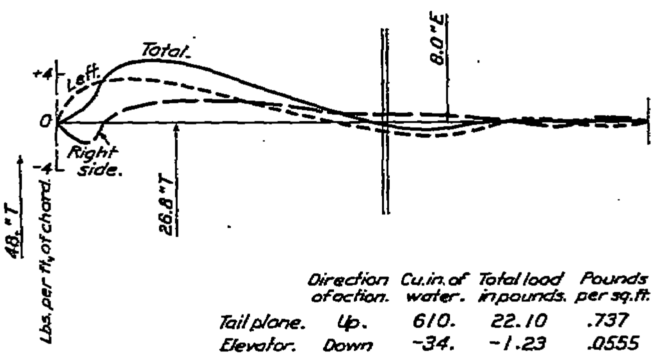
CASE II. 900 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	800.	29.00	.964
Elevator.	Down.	-54.	-1.95	.088
Total.	Up.		27.05	.518

Fig. 155. Elevator moment about hinge = -24.4 in. lbs.

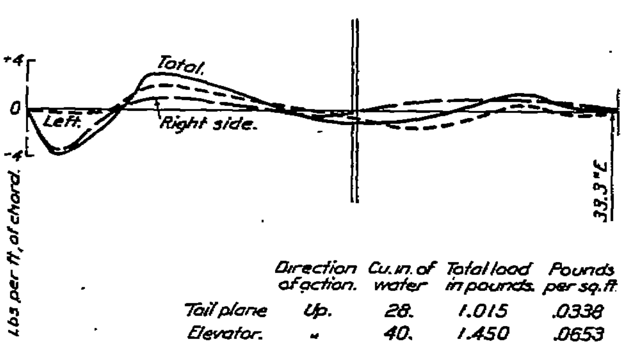
CASE II. 900 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	610.	22.10	.737
Elevator.	Down	-34.	-1.23	.0555
Total.	Up.		20.87	.400

Fig. 156. Elevator moment about hinge = -9.85 in. lbs.

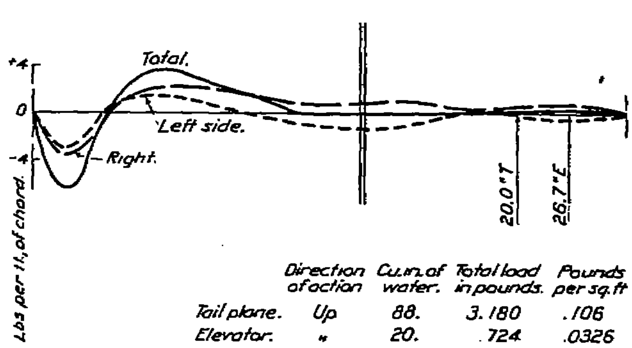
CASE II. 900 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water	Total load in pounds.	Pounds per sq. ft.
Tail plane	Up.	28.	1.015	.0338
Elevator.	"	40.	1.450	.0653
Total.	"		2.465	0471

Fig. 157. Elevator moment about hinge = 48.4 in. lbs.

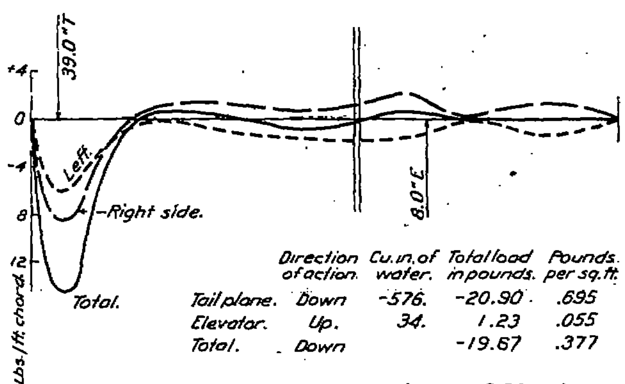
CASE II. 900 R.P.M. 70 M.P.H.



	Direction of action	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft
Tail plane.	Up	88.	3.180	.106
Elevator.	"	20.	.724	.0326
Total.	"		3.904	0746

Fig. 158. Elevator moment about hinge = 19.3 in. lbs.

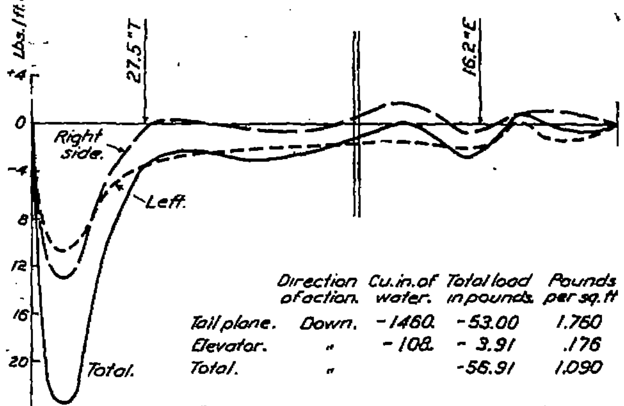
CASE II. 900 R.P.M. 80 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down	-576.	-20.90	.695
Elevator.	Up.	34.	1.23	.055
Total.	Down		-19.67	.377

Fig. 159. Elevator moment about hinge = 9.84 in.lbs.

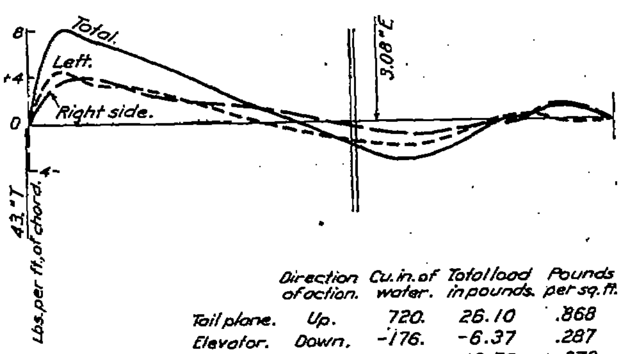
CASE II. 900 R.P.M. 90 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-1460.	-53.00	1.760
Elevator.	"	-108.	-3.91	.176
Total.	"		-56.91	1.090

Fig. 160. Elevator moment about hinge = -63.4 in.lbs.

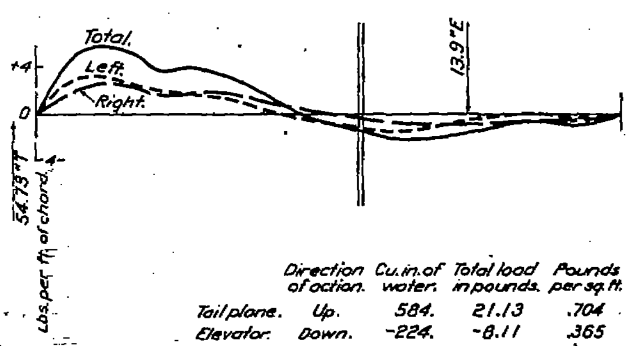
CASE II. 600 R.P.M. 45 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	720.	26.10	.868
Elevator.	Down.	-176.	-6.37	.287
Total.	Up.		19.73	.378

Fig. 161. Elevator moment about hinge = 19.6 in.lbs.

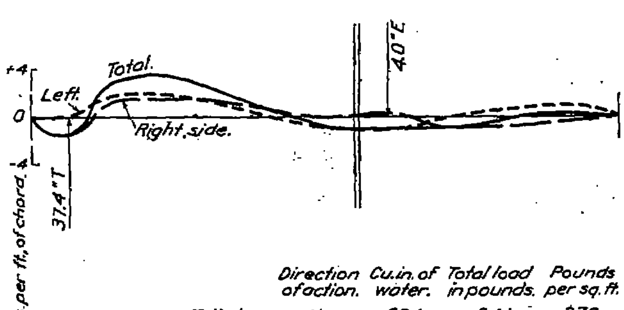
CASE II. 600 R.P.M. 50 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	584.	21.13	.704
Elevator.	Down.	-224.	-8.11	.365
Total.	Up.		13.02	.249

Fig. 162. Elevator moment about hinge = 113.0 in.lbs.

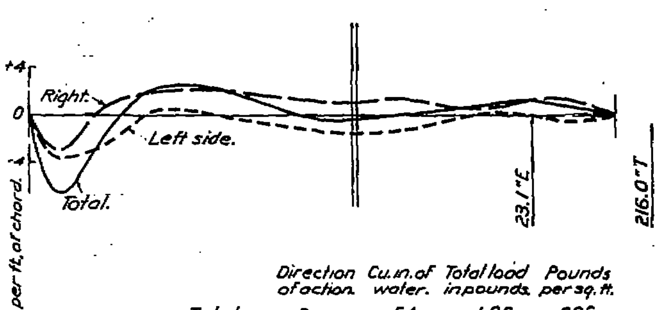
CASE II. 600 R.P.M. 60 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	224.	8.11	.270
Elevator.	Down.	-68.	-2.46	.111
Total.	Up		5.65	.108

Fig. 163. Elevator moment about hinge = -9.85 in.lbs.

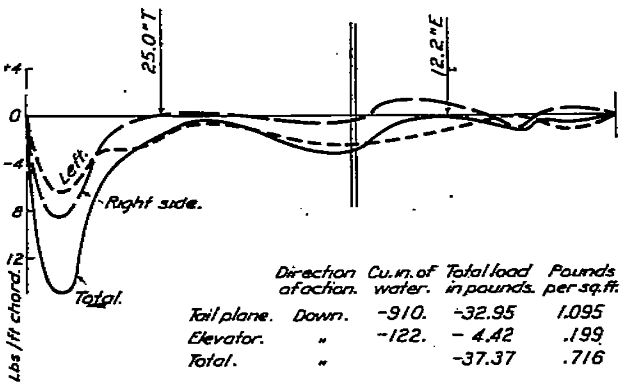
CASE II. 600 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-54.	-1.96	.065
Elevator	Up.	88.	3.19	.143
Total.	"		1.23	.0236

Fig. 164. Elevator moment about hinge = 73.7 in.lbs.

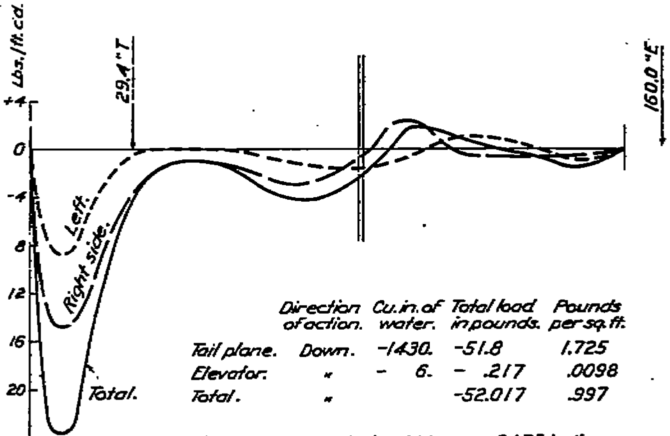
CASE II. 600 R.P.M. 80 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-910.	-32.95	1.095
Elevator.	"	-122.	- 4.42	.199
Total.	"		-37.37	.716

Fig. 165. Elevator moment about hinge = -54.0 in. lbs.

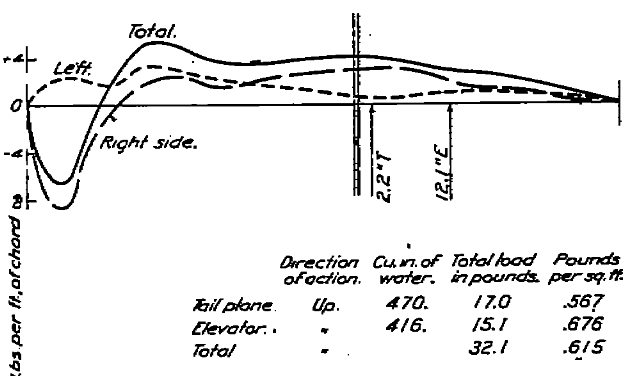
CASE II. 600 R.P.M. 100 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-1430.	-51.8	1.725
Elevator.	"	- 6.	- .217	.0098
Total.	"		-52.017	.997

Fig. 166. Elevator moment about hinge = -34.75 in. lbs.

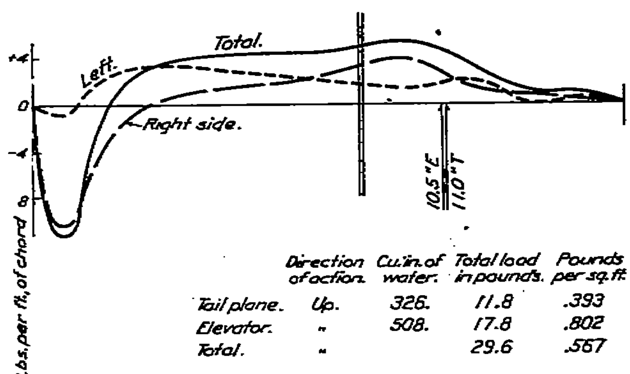
CASE III 1400 R.P.M. 45 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	470.	17.0	.567
Elevator.	"	416.	15.1	.676
Total	"		32.1	.615

Fig. 167. Elevator moment about hinge = 182.7 in. lbs.

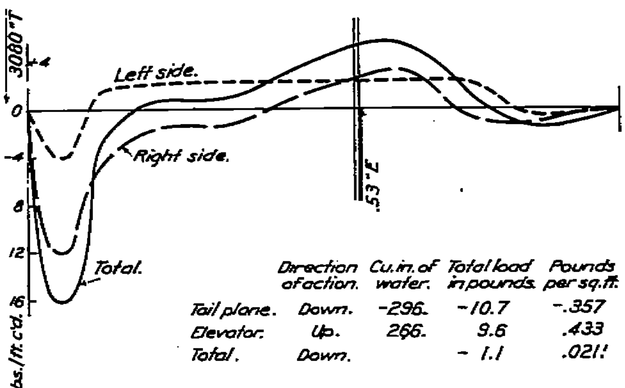
CASE III. 1400 R.P.M. 50 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	326.	11.8	.393
Elevator.	"	508.	17.8	.802
Total.	"		29.6	.567

Fig. 168. Elevator moment about hinge = 187 in. lbs.

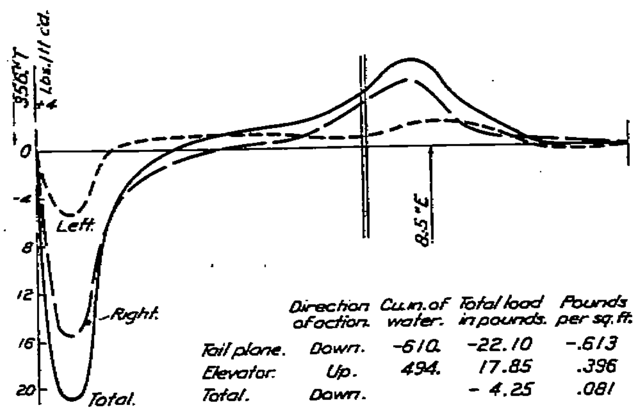
CASE III. 1400 R.P.M. 60 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-296.	-10.7	-.357
Elevator.	Up.	266.	9.6	.433
Total.	Down.		- 1.1	.021!

Fig. 169. Elevator moment about hinge = 5.08 in. lbs.

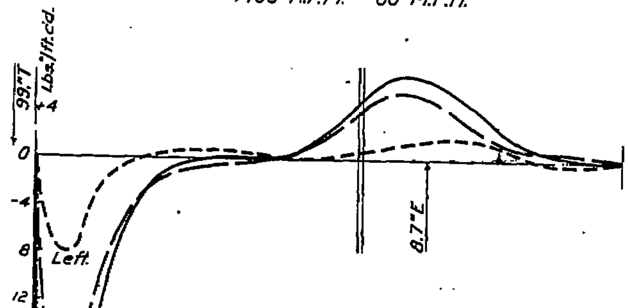
CASE III. 1400 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-610.	-22.10	-.613
Elevator.	Up.	494.	17.85	.396
Total.	Down.		- 4.25	.081

Fig. 170 Elevator moment about hinge = 152. in. lbs.

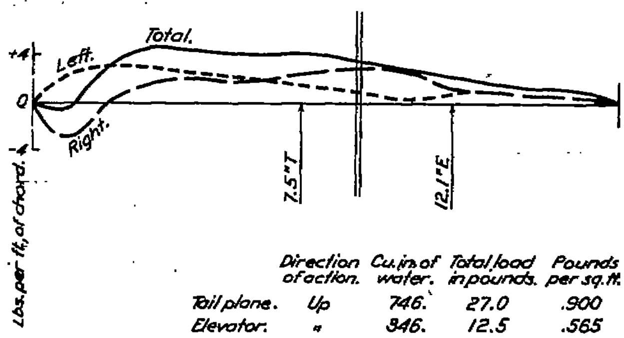
CASE III 1400 R.P.M. 80 M.P.H.



	Direction of action	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-1094.	-39.6	1.320
Elevator.	Up.	582	21.1	.950
Total	Down.		-18.5	.354

Fig. 171 Elevator moment about hinge = 183.5 in. lbs.

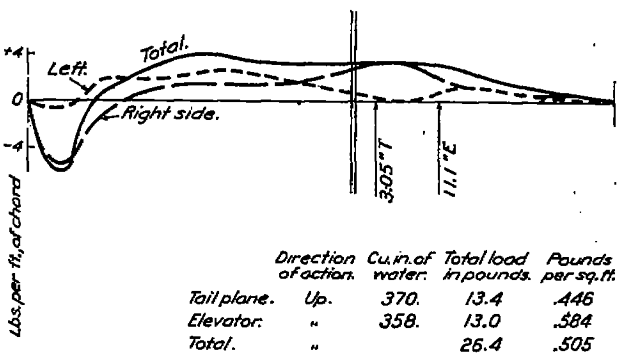
CASE III. 1200 R.P.M. 45 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up	746.	27.0	.900
Elevator.	"	346.	12.5	.565
Total.	"		39.5	.756

Fig. 172. Elevator moment about hinge = 151.3 in. lbs.

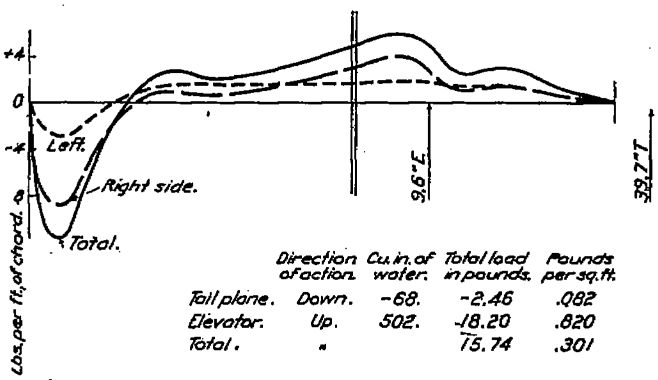
CASE III. 1200 R.P.M. 50 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	370.	13.4	.446
Elevator.	"	358.	13.0	.584
Total.	"		26.4	.505

Fig. 173. Elevator moment about hinge = 144.3 in. lbs.

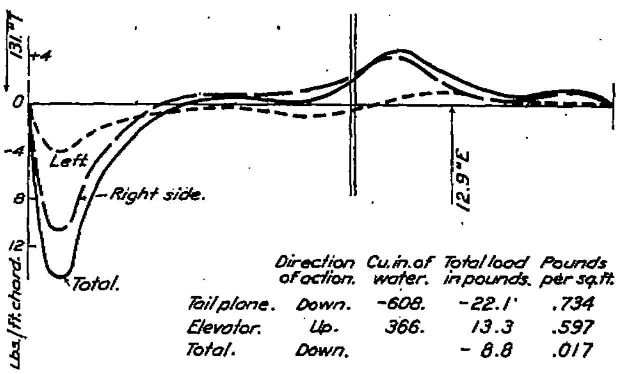
CASE III. 1200 R.P.M. 60 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-68.	-2.46	.082
Elevator.	Up.	502.	18.20	.820
Total.	"		15.74	.301

Fig. 174. Elevator moment about hinge = 175.0 in. lbs.

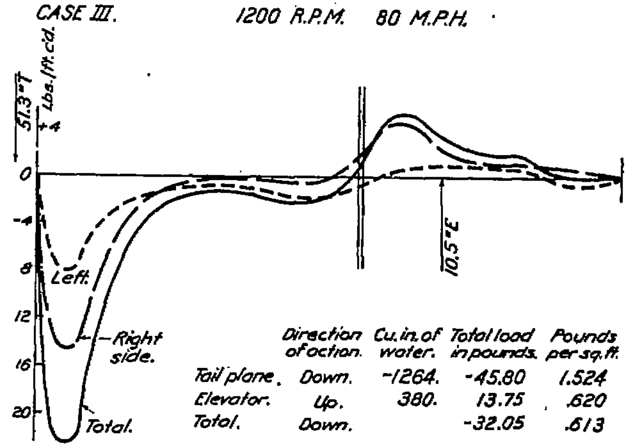
CASE III. 1200 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-608.	-22.1	.734
Elevator.	Up.	366.	13.3	.597
Total.	Down.		- 8.8	.017

Fig. 175. Elevator moment about hinge = 171.6 in. lbs.

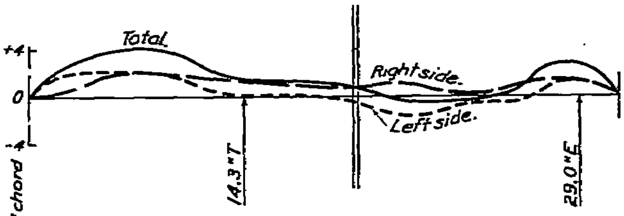
CASE III. 1200 R.P.M. 80 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-1264.	-45.80	1.524
Elevator.	Up.	380.	13.75	.620
Total.	Down.		-32.05	.613

Fig. 176. Elevator moment about hinge = 144.4 in. lbs.

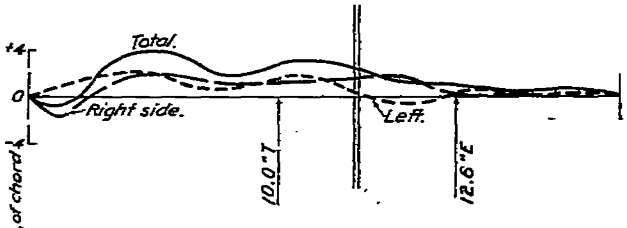
CASE III. 900 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	530.	19.20	.638
Elevator.	"	110.	3.98	.180
Total.	"		23.18	.444

Fig. 177. Elevator moment about hinge = 116.0 in. lbs.

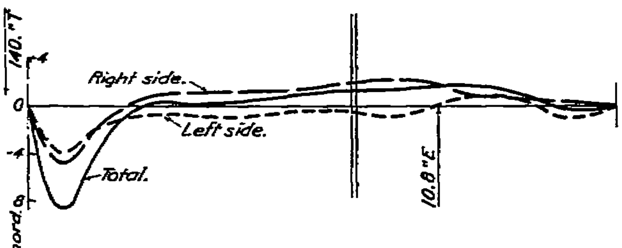
CASE III. 900 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	480.	17.40	.579
Elevator.	"	172	6.23	.138
Total.	"		23.63	.452

Fig. 178. Elevator moment about hinge = 78.5 in. lbs.

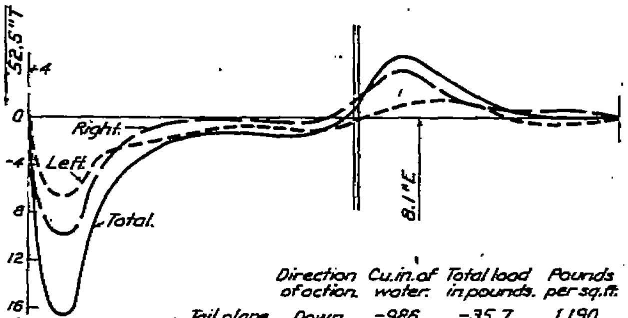
CASE III. 900 R.P.M. 60 M.P.H.



	Direction of action	Cu. in. of water	Total load in pounds	Pounds per sq. ft.
Tail plane.	Down.	-262.	-9.50	.316
Elevator.	Up.	176.	6.37	.141
Total.	Down.		-3.13	.060

Fig. 179. Elevator moment about hinge = 63.6 in. lbs.

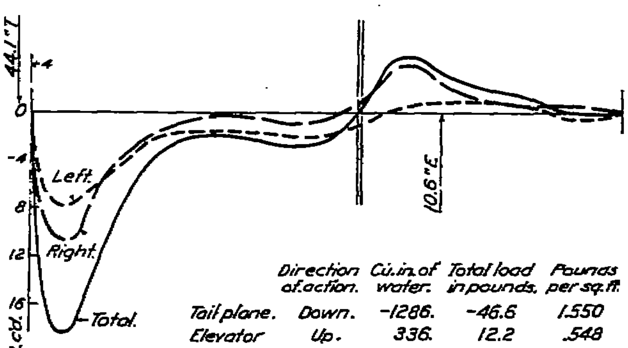
CASE III. 900 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-986.	-35.7	1.190
Elevator.	Up.	324.	11.7	.528
Total.	Down.		-24.0	460

Fig. 180. Elevator moment about hinge = 94.8 in. lbs.

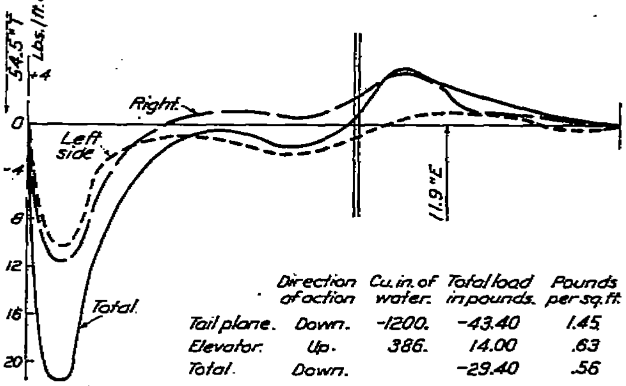
CASE III. 900 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1286.	-46.6	1.550
Elevator	Up.	336.	12.2	.548
Total.	Down.		-34.4	.659

Fig. 181. Elevator moment about hinge = 129. in. lbs.

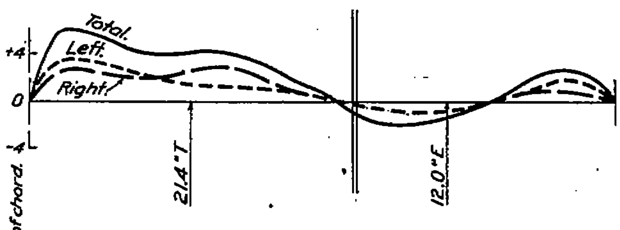
CASE III. — 900 R.P.M. 90 M.P.H.



	Direction of action	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1200.	-43.40	1.45
Elevator.	Up.	386.	14.00	.63
Total.	Down.		-29.40	.56

Fig. 182. Elevator moment about hinge = 166.0 in. lbs.

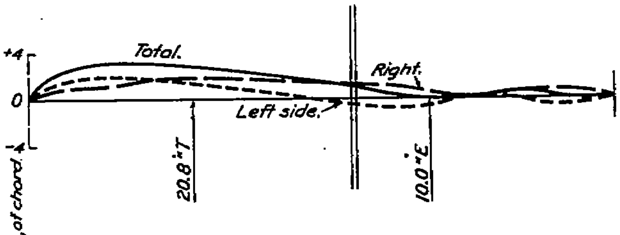
CASE III. 600 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	778.	28.20	.940
Elevator.	"	20.	.72	.033
Total.	"		28.92	.554

Fig. 183. Elevator moment about hinge = 8.64 in. lbs.

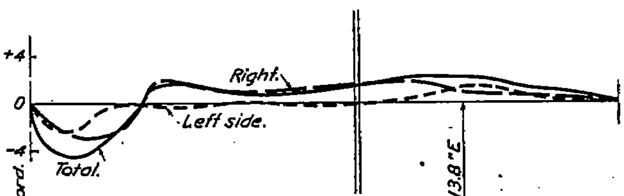
CASE III. 600 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	508.	18.40	.614
Elevator.	"	40.	1.45	.065
Total.	"		19.85	.380

Fig. 184. Elevator moment about hinge = 14.5 in. lbs.

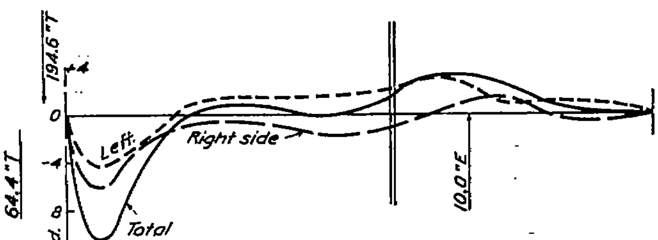
CASE III. 600 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-70.	-2.53	.084
Elevator.	Up.	276.	10.00	.450
Total	"		7.47	.143

Fig. 185. Elevator moment about hinge = 138. in. lbs.

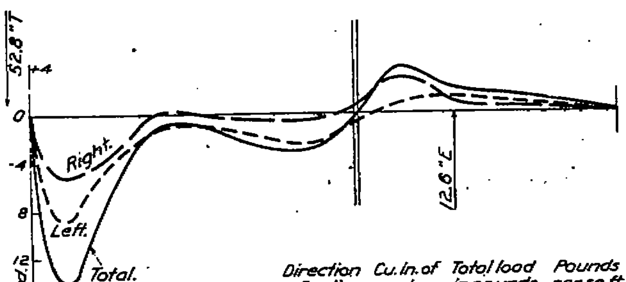
CASE III. 600 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down	420.	-15.2	.507
Elevator.	Up.	318.	11.5	.578
Total.	Down		-3.7	.078

Fig. 186. Elevator moment about hinge = 115. in. lbs.

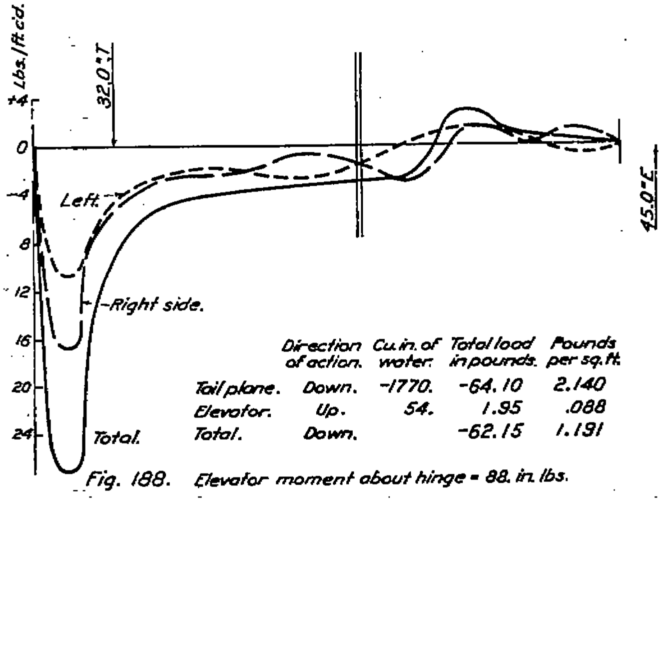
CASE III. 600 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-912.	-33.00	1.100
Elevator.	Up.	308.	11.16	.503
Total.	Down.		-21.84	.418

Fig. 187. Elevator moment about hinge = 140.6 in lbs.

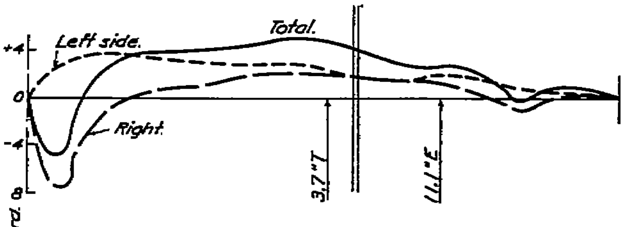
CASE III. 600 R.P.M. 100 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1770.	-64.10	2.140
Elevator.	Up.	54.	1.95	.088
Total.	Down.		-62.15	1.191

Fig. 188. Elevator moment about hinge = 88. in. lbs.

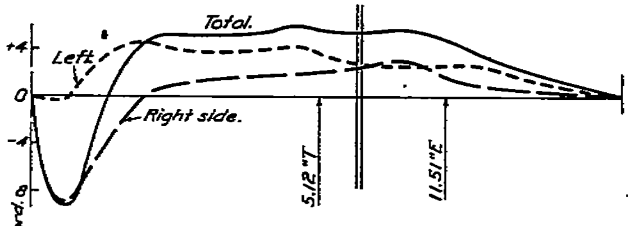
CASE IV. 1400 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	608.	22.0	.733
Elevator.	"	306.	11.1	.500
Total.	"		33.1	.634

Fig. 189. Elevator moment about hinge = 123.2 in. lbs.

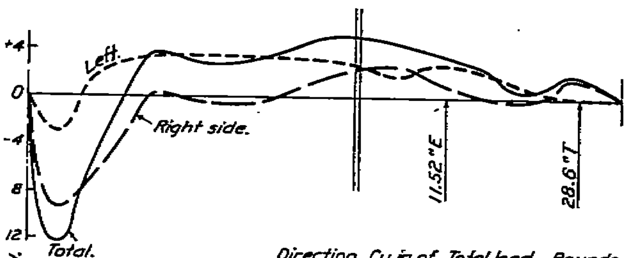
CASE IV. 1400 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	536.	19.39	.647
Elevator.	"	576.	20.90	.940
Total.	"		40.29	.771

Fig. 190. Elevator moment about hinge = 241.0 in. lbs.

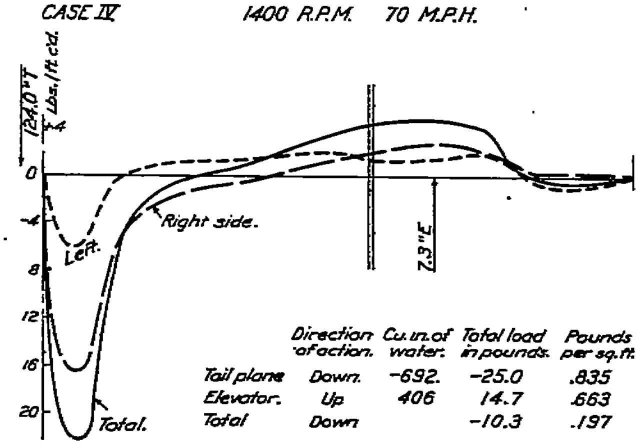
CASE IV. 1400 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up	94.	3.4	.113
Elevator.	"	448.	16.2	.731
Total.	"		19.6	.376

Fig. 191 Elevator moment about hinge = 187.0 in. lbs.

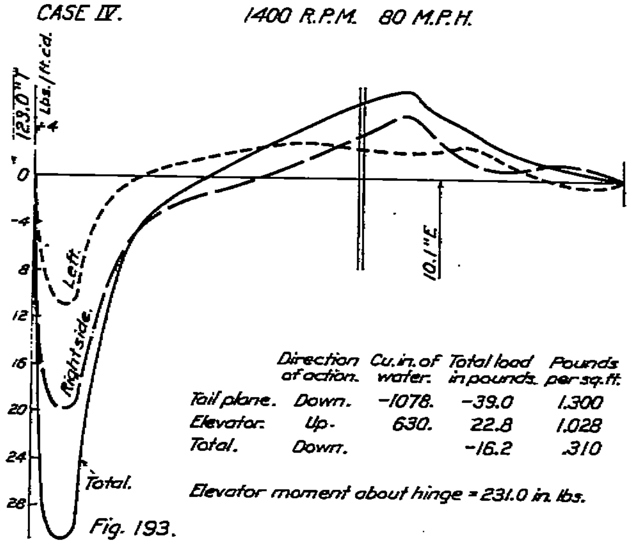
CASE IV 1400 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Down.	-692.	-25.0	.835
Elevator.	Up	406	14.7	.663
Total	Down		-10.3	.197

Fig. 192. Elevator moment about hinge = 107.5 in. lbs.

CASE IV. 1400 R.P.M. 80 M.P.H.

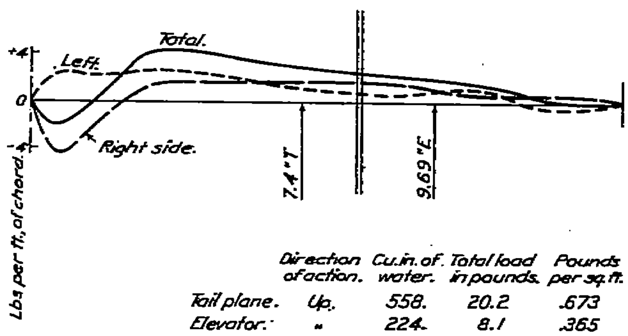


	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1078.	-39.0	1.300
Elevator.	Up.	630.	22.8	1.028
Total.	Down.		-16.2	.310

Elevator moment about hinge = 231.0 in. lbs.

Fig. 193.

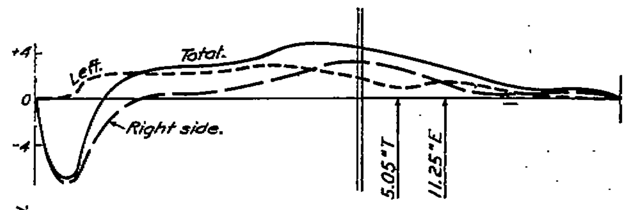
CASE IV. 1200 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of. water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	558.	20.2	.673
Elevator.	"	224.	8.1	.365
Total.	"		28.3	.542

Fig. 194. Elevator moment about hinge = 78.5 in. lbs.

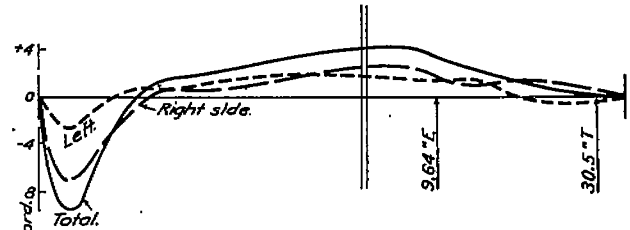
CASE IV. 1200 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	374.	13.55	.450
Elevator.	"	352.	12.75	.575
Total.	"		26.30	.504

Fig. 195. Elevator moment about hinge = 143.5 in. lbs.

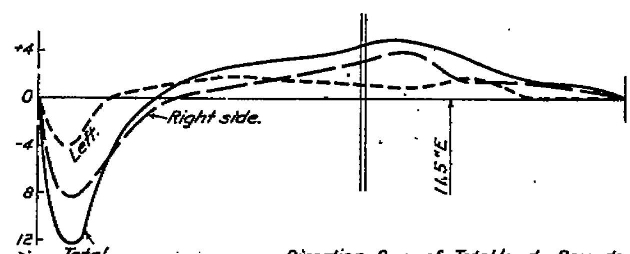
CASE IV. 1200 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	40.	1.45	.0483
Elevator.	"	374.	13.55	.610
Total.	"		15.00	.287

Fig. 196 Elevator moment about hinge = 130.5 in. lbs.

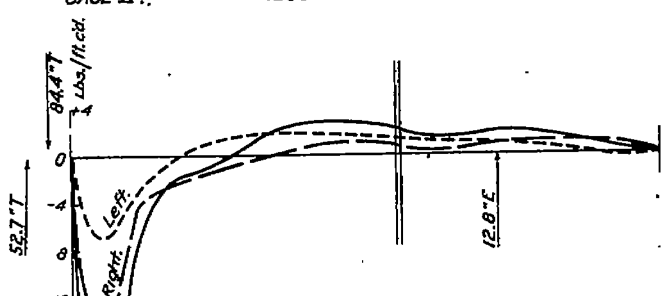
CASE IV. 1200 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-124.	-4.5	.149
Elevator.	Up.	496.	18.0	.810
Total	"		13.5	.258

Fig. 197. Elevator moment about hinge = 207. in. lbs.

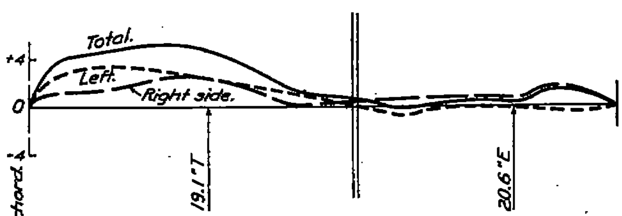
CASE IV. 1200 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds	Pounds per sq. ft.
Tail plane	Down	-610.	-22.10	.735
Elevator	Up.	244.	8.84	.398
Total	Down		-13.26	.254

Fig 198 Elevator moment about hinge = 113. in. lbs.

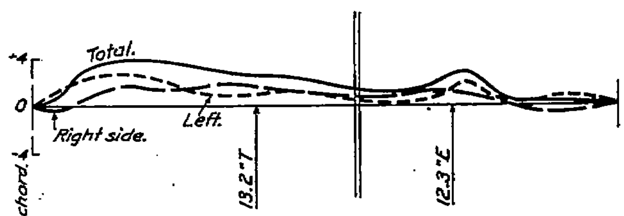
CASE IV. 900 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Up.	712	25.80	.860
Elevator.	"	108.	3.91	.176
Total.	"		29.71	.519

Fig. 199. Elevator moment about hinge = 80.5 in. lbs.

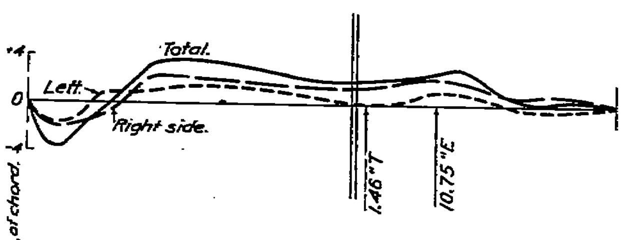
CASE IV 900 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up	522.	18.9	.630
Elevator.	"	210.	7.6	.342
Total.	"		26.5	.508

Fig. 200. Elevator moment about hinge = 93.5 in. lbs.

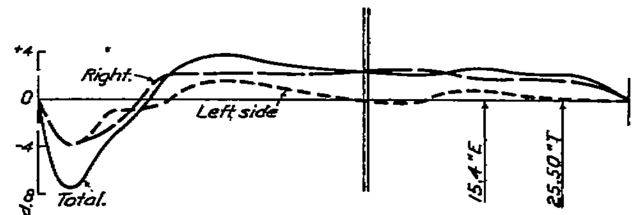
CASE IV 900 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	292.	10.59	.352
Elevator.	"	264.	9.56	.430
Total.	"		20.15	.386

Fig. 201 Elevator moment about hinge = 102.5 in. lbs.

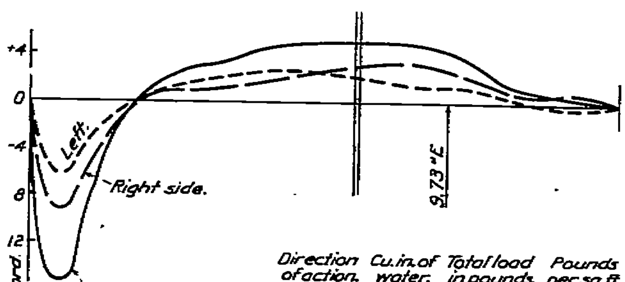
CASE IV. 900 R.P.M. 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	68.	2.46	.0820
Elevator.	"	386.	14.00	.630
Total.	"		16.46	.315

Fig. 202. Elevator moment about hinge = 216.0 in. lbs.

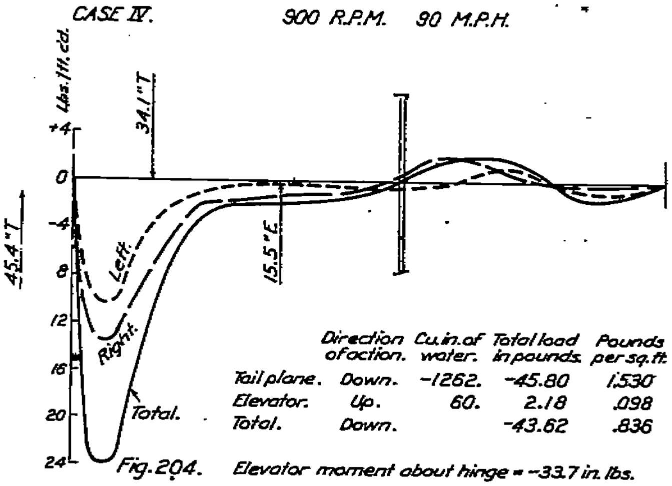
CASE IV. 900 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-34.	-1.23	.041
Elevator.	Up.	488.	17.70	.795
Total.	"		16.47	.315

Fig. 203. Llevator moment aboul hinge = 172.0 in. lbs.

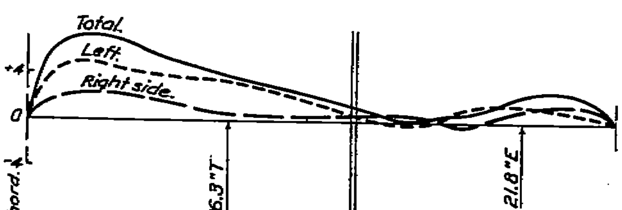
CASE IV. 900 R.P.M. 90 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-1262.	-45.80	1.530
Elevator.	Up.	60.	2.18	.098
Total.	Down.		-43.62	.836

Fig. 204. Elevator moment about hinge = -33.7 in. lbs.

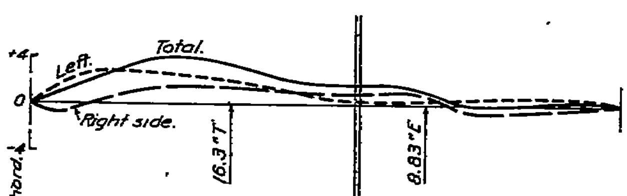
CASE IV. 600 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	970.	35.10	1.170
Elevator.	"	230.	8.34	.375
Total.	"		43.44	.832

Fig. 205. Elevator moment about hinge = 182.0 in. lbs.

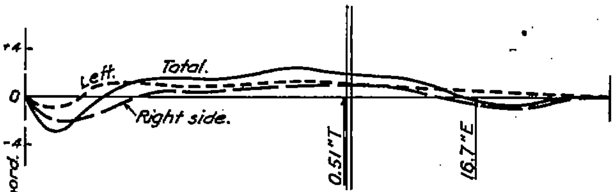
CASE IV. 600 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water	Total load in pounds.	Pounds per sq. ft.
Tail plane	Up	522.	18.9	.630
Elevator.	"	116	4.2	.189
Total.	"		23.1	.443

Fig. 206. Elevator moment about hinge = 37.1 in. lbs

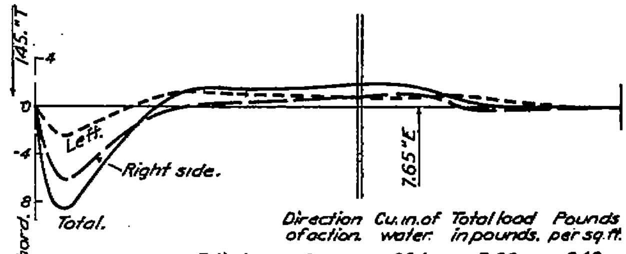
CASE IV. 600 R.P.M. 60 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Up.	182.	6.59	.219
Elevator.	"	82.	2.97	.134
Total	"		9.56	.183

Fig. 207. Elevator moment about hinge = 49.6 in. lbs.

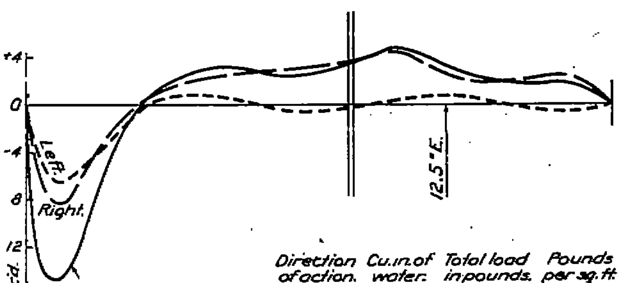
CASE IV 600 R.P.M 70 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Down.	-204.	-7.39	.246
Elevator.	Up.	116.	4.20	.189
Total	Down.		-3.19	.0611

Fig. 208 Elevator moment about hinge = 32.1 in. lbs.

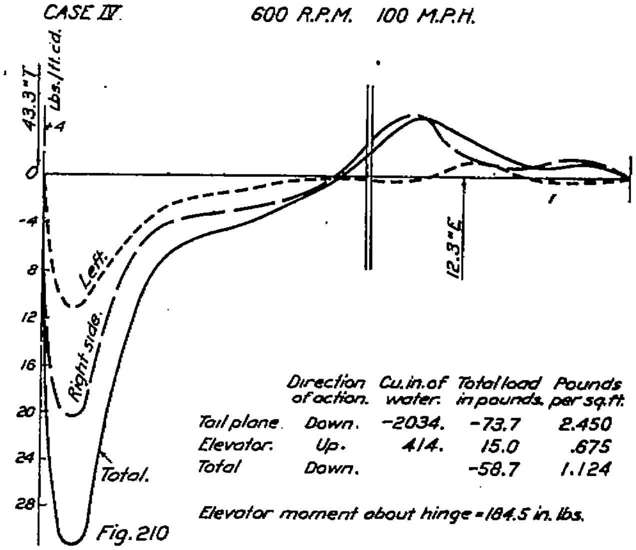
CASE IV. 600 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-346.	-12.5	.417
Elevator.	Up.	496.	18.0	.810
Total.	"		5.5	.105

Fig. 209 Elevator moment about hinge = 225.1 in. lbs.

CASE IV. 600 R.P.M. 100 M.P.H.

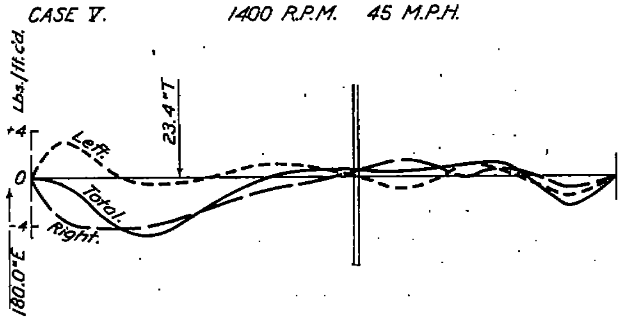


	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane	Down.	-2034.	-73.7	2.450
Elevator.	Up.	414.	15.0	.675
Total	Down.		-58.7	1.124

Elevator moment about hinge = 184.5 in. lbs.

Fig. 210

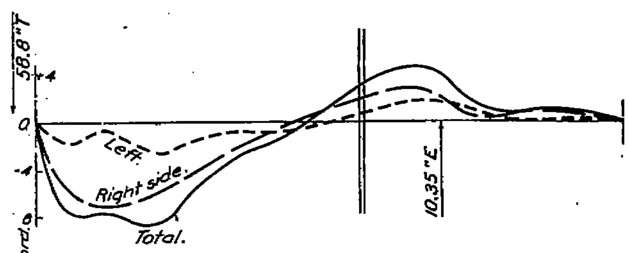
CASE V. 1400 R.P.M. 45 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-386.	-14.000	.466
Elevator.	Up.	6.	.217	.0098
Total.	Down.		-13.783	.264

Fig. 211. Elevator moment about hinge = -39.1 in. lbs.

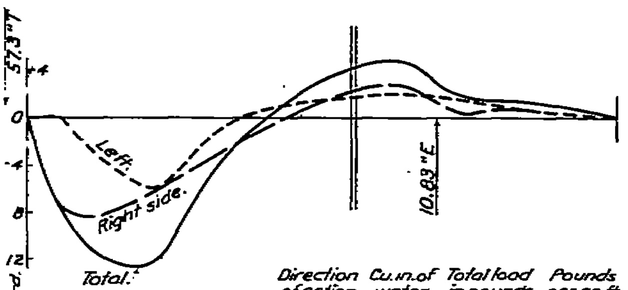
CASE V. 1400 R.P.M. 50 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-942.	-34.1	1.137
Elevator.	Up.	400.	14.5	.652
Total.	Down.		-19.6	.376

Fig. 212 Elevator moment about hinge = 150.0 in. lbs.

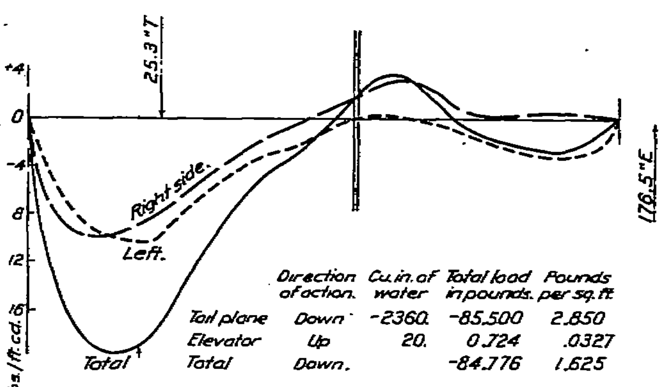
CASE V 1400 R.P.M. 60 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-1082.	-39.2	1.305
Elevator.	Up.	404.	14.6	.659
Total.	Down.		-24.6	.471

Fig. 213. Elevator moment about hinge = 158.5 in. lbs.

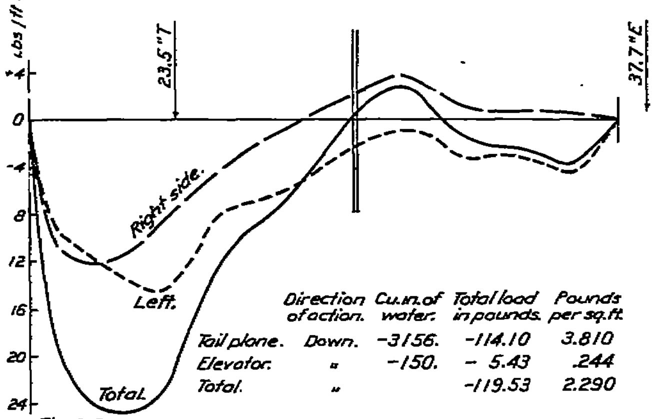
CASE V 1400 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water	Total load in pounds.	Pounds per sq.ft.
Tail plane	Down	-2360.	-85.500	2.850
Elevator	Up	20.	0.724	.0327
Total	Down.		-84.776	1.625

Fig. 214 Elevator moment about hinge = 127.5 in lbs.

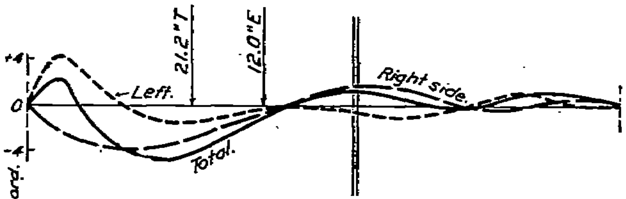
CASE V. 1400 R.P.M. 80 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-3156.	-114.10	3.810
Elevator.	"	-150.	- 5.43	.244
Total.	"		-119.53	2.290

Fig. 215. Elevator moment about hinge = -205.0 in. lbs.

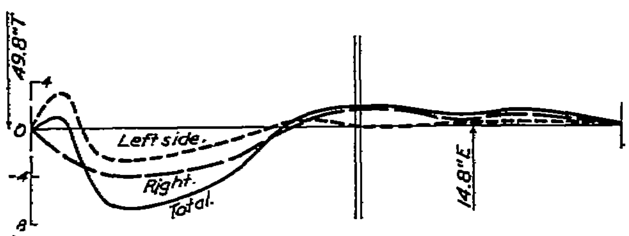
CASE V. 1200 R.P.M. 45 M.P.H



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-496.	-18.00	.600
Elevator.	"	- 34.	- 1.23	.055
Total	"		-19.23	.369

Fig. 216. Elevator moment about hinge = 14.8 in. lbs.

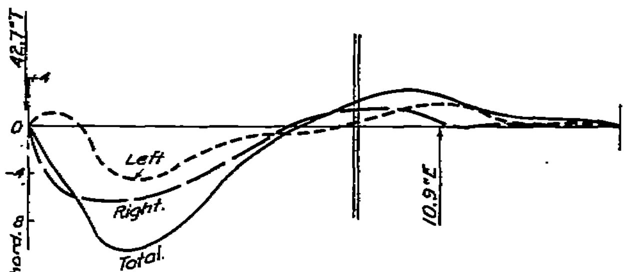
CASE V. 1200 R.P.M 50 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane	Down	-570.	-20.65	.688
Elevator	Up.	210.	7.60	.342
Total	Down.		-13.05	.250

Fig. 217 Elevator moment about hinge = 112.5 in. lbs.

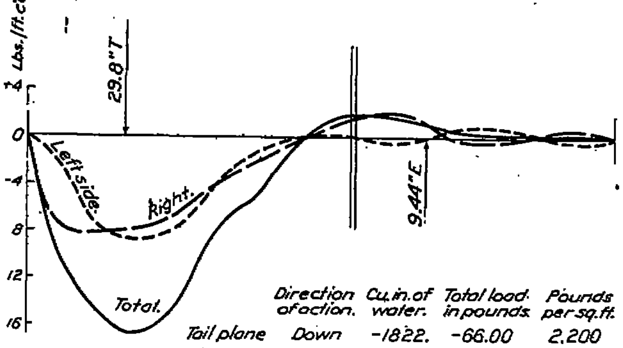
CASE V 1200 R.P.M. 60 M.P.H.



	Direction of action	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane	Down	-1038	-37.6	1.250
Elevator	Up	298.	10.8	.486
Total	Down.		-26.8	.510

Fig. 218 Elevator moment about hinge = 118.0 in. lbs

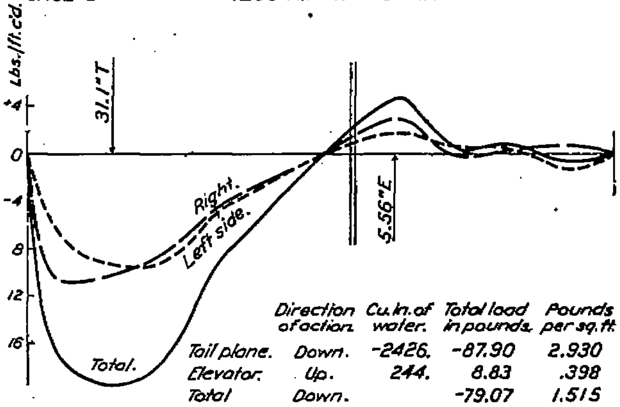
CASE V. 1200 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane	Down	-1822.	-66.00	2.200
Elevator	Up.	122	4.42	.199
Total	Down		-61.58	1.180

Fig. 219 Elevator moment about hinge = 41.75 in.lbs.

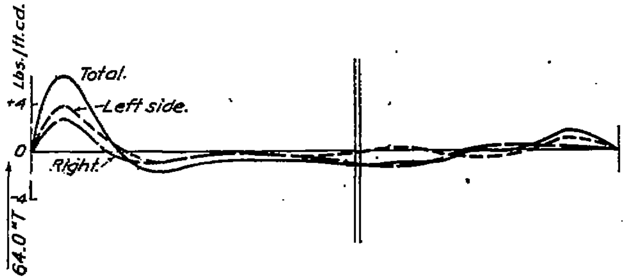
CASE V. 1200 R.P.M. 80 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-2426.	-87.90	2.930
Elevator.	Up.	244.	8.83	.398
Total	Down.		-79.07	1.515

Fig. 220. Elevator moment about hinge = 49.1 in.lbs.

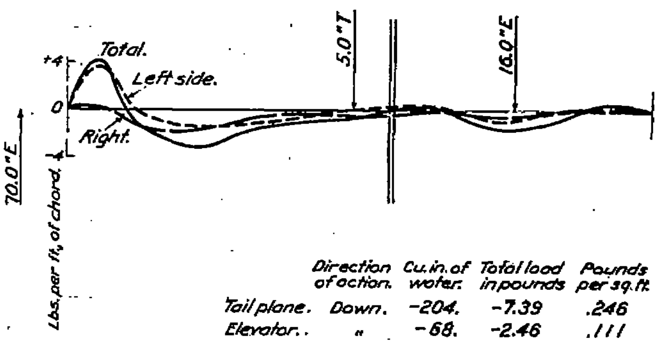
CASE V. 900 R.P.M. 45 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up	48.	1.740	.0580
Elevator.	"	20.	.725	.0326
Total.	"		2.465	.0469

Fig 221. Elevator moment about hinge = 50.7 in.lbs.

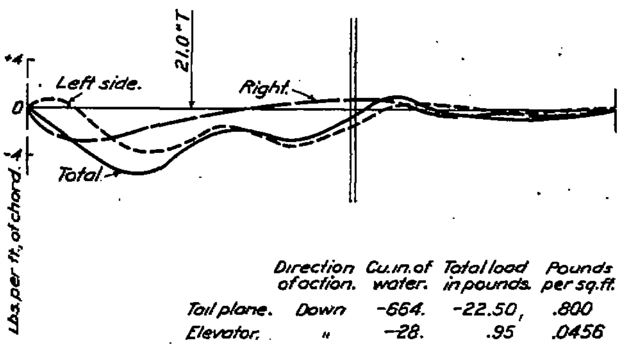
CASE V. 900 R.P.M. 50 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds	Pounds per sq.ft.
Tail plane.	Down.	-204.	-7.39	.246
Elevator.	"	-68.	-2.46	.111
Total.	"		-9.85	.189

Fig. 222. Elevator moment about hinge = -39.4 in.lbs.

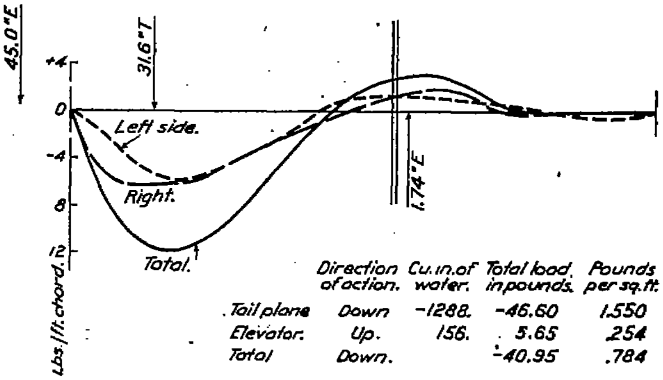
CASE V 900 R.P.M. 60 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down	-664.	-22.50	.800
Elevator.	"	-28.	.95	.0456
Total.	"		-23.45	.450

Fig. 223 Elevator moment about hinge = -42.8 in.lbs.

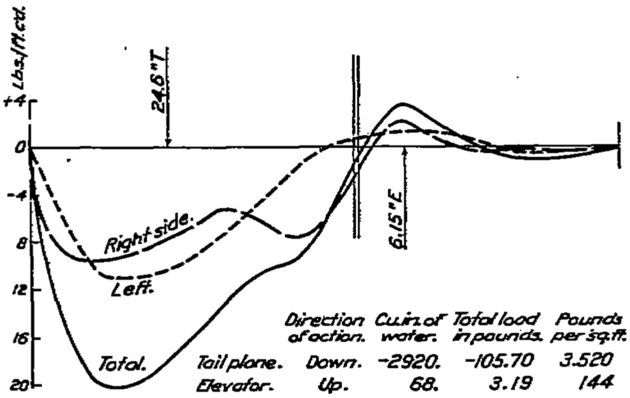
CASE V. 900 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane	Down	-1288.	-46.60	1.550
Elevator.	Up.	156.	5.65	.254
Total	Down.		-40.95	.784

Fig. 224. Elevator moment about hinge = 9.84 in.lbs.

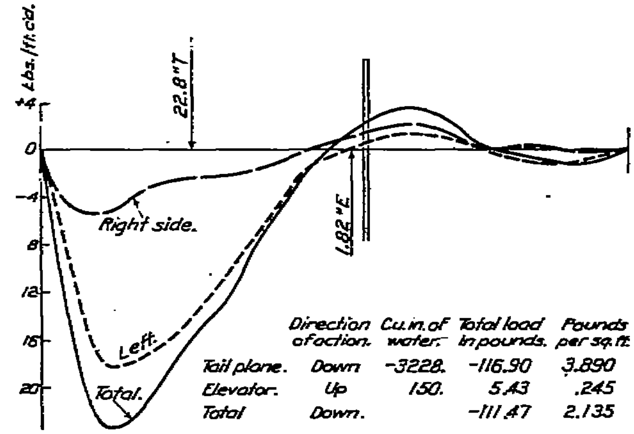
CASE V 900 R.P.M. 80 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-2920.	-105.70	3.520
Elevator.	Up.	68.	3.19	.144
Total.	Down.		-102.51	1.964

Fig. 225. Elevator moment about hinge = 19.63 in.lbs.

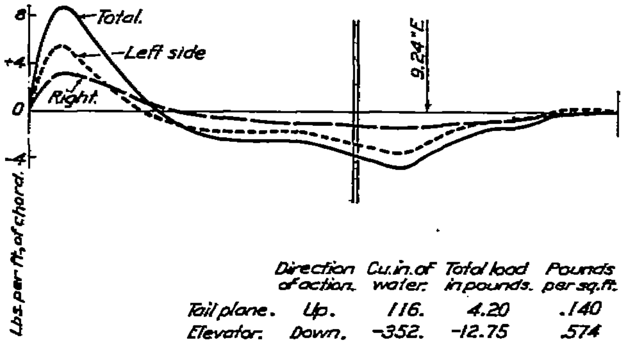
CASE V. 900 R.P.M. 90 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down	-3228.	-116.90	3.890
Elevator.	Up	150.	5.43	.245
Total	Down.		-111.47	2.135

Fig. 226. Elevator moment about hinge = -9.89 in.lbs.

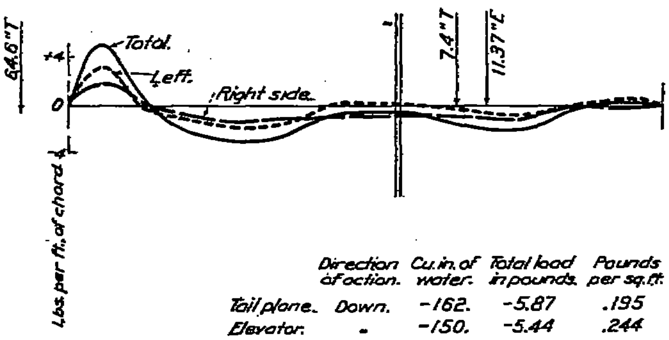
CASE V. 600 R.P.M 45 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Up.	116.	4.20	.140
Elevator.	Down.	-352.	-12.75	.574
Total.	"		- 8.55	.164

Fig. 227. Elevator moment about hinge = 117.9 in.lbs.

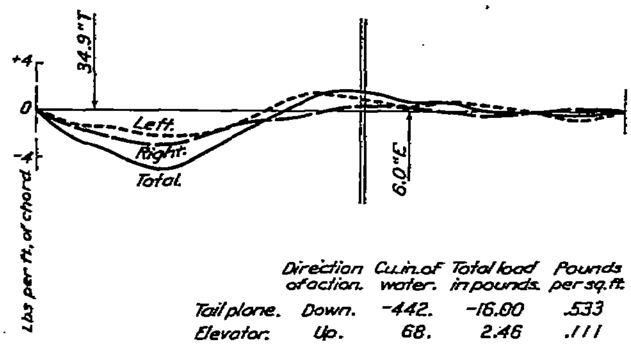
CASE V. 600 R.P.M. 50 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-162.	-5.87	.195
Elevator.	"	-150.	-5.44	.244
Total.	"		-11.31	.217

Fig. 228. Elevator moment about hinge = -61.8 in.lbs.

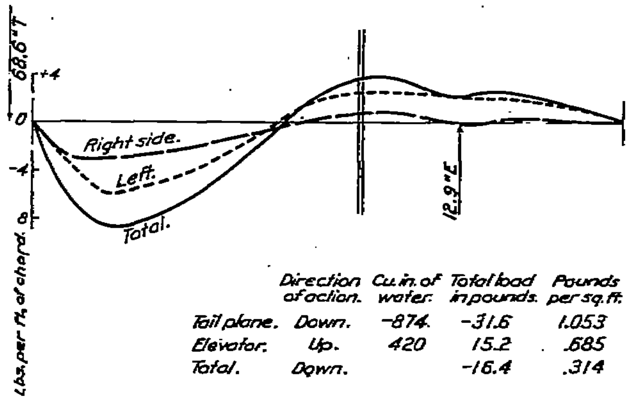
CASE V. 600 R.P.M. 60 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-442.	-16.00	.533
Elevator.	Up.	68.	2.46	.111
Total.	Down.		-13.54	.259

Fig. 229. Elevator moment about hinge = 14.75 in.lbs.

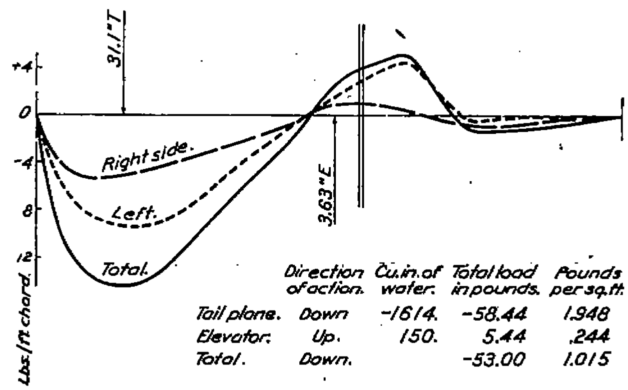
CASE V. 600 R.P.M. 70 M.P.H.



	Direction of action.	Cu.in.of water.	Total load in pounds.	Pounds per sq.ft.
Tail plane.	Down.	-874.	-31.6	1.053
Elevator.	Up.	420	15.2	.685
Total.	Down.		-16.4	.314

Fig. 230. Elevator moment about hinge = 196.1 in.lbs.

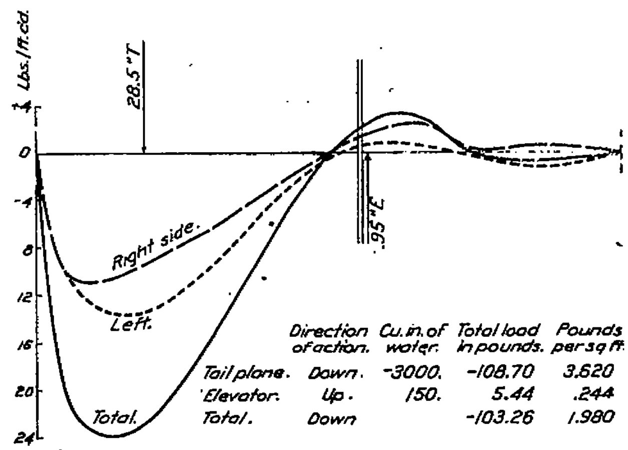
CASE V. 600 R.P.M. 80 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down	-1614.	-58.44	1.948
Elevator.	Up.	150.	5.44	.244
Total.	Down.		-53.00	1.015

Fig. 231. Elevator moment about hinge = -19.75 in. lbs.

CASE V. 600 R.P.M. 100 M.P.H.



	Direction of action.	Cu. in. of water.	Total load in pounds.	Pounds per sq. ft.
Tail plane.	Down.	-3000.	-108.70	3.620
Elevator.	Up.	150.	5.44	.244
Total.	Down		-103.26	1.980

Fig. 232. Elevator moment about hinge = 5.16 in. lbs.

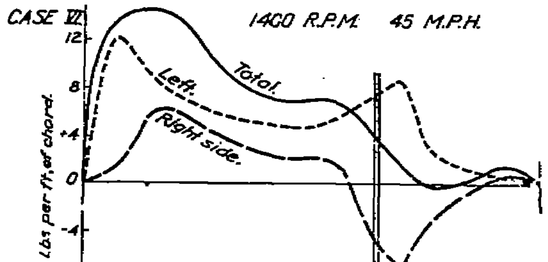


Fig. 233.

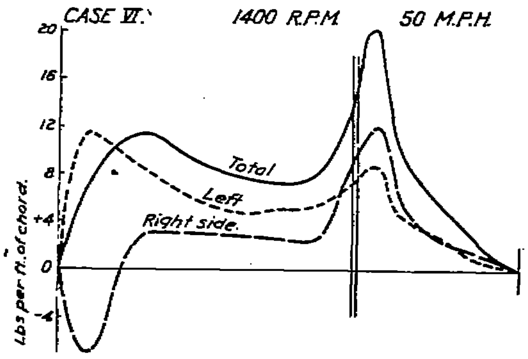


Fig. 234.

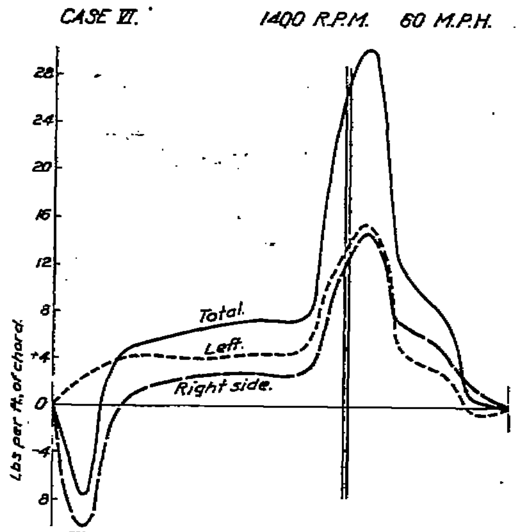


Fig. 235.

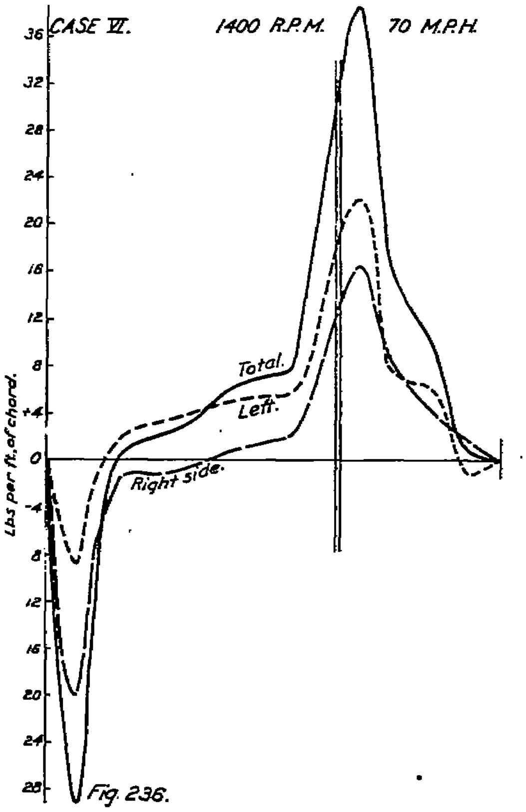


Fig. 236.

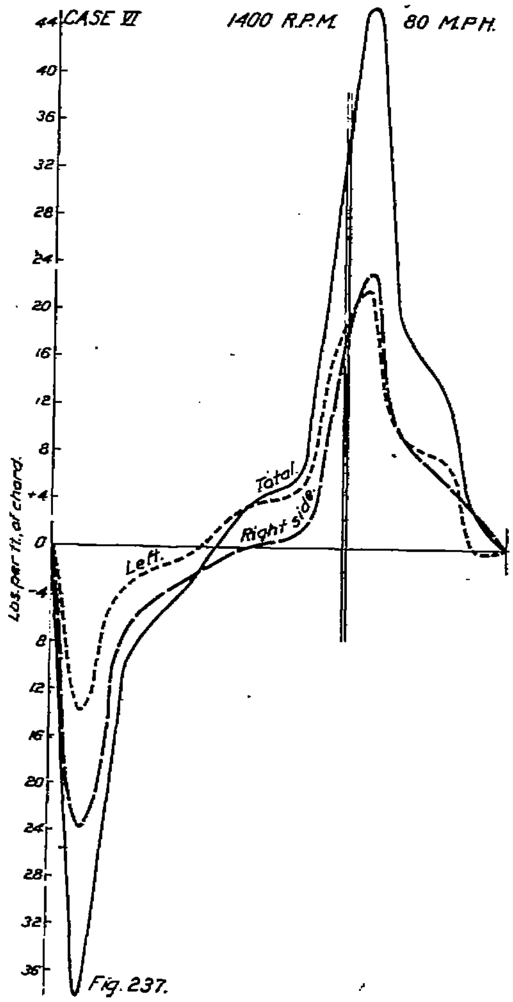


Fig. 237.

CASE VI. 600 R.P.M. 50 M.P.H.

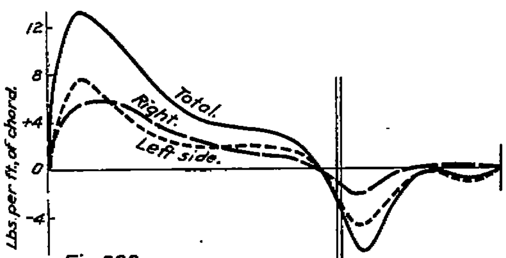


Fig. 238.

CASE VI. 600 R.P.M. 60 M.P.H.

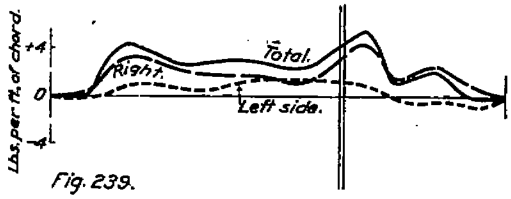


Fig. 239.

CASE VI. 600 R.P.M. 70 M.P.H.

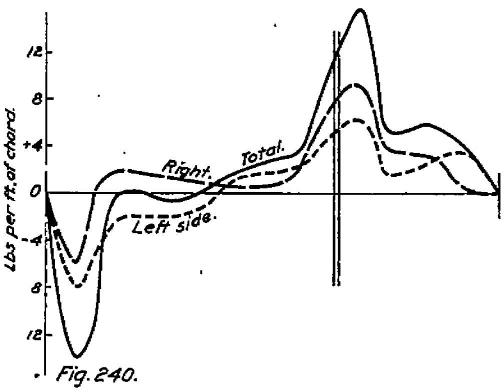


Fig. 240.

CASE VI. 600 R.P.M. 80 M.P.H.

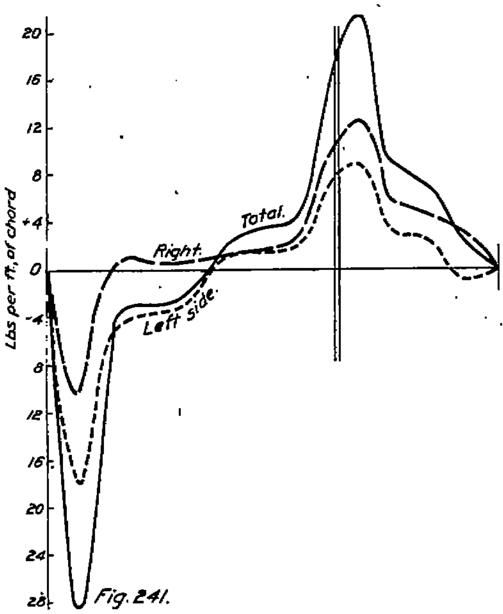


Fig. 241.

CASE VI. 600 R.P.M. 100 M.P.H.

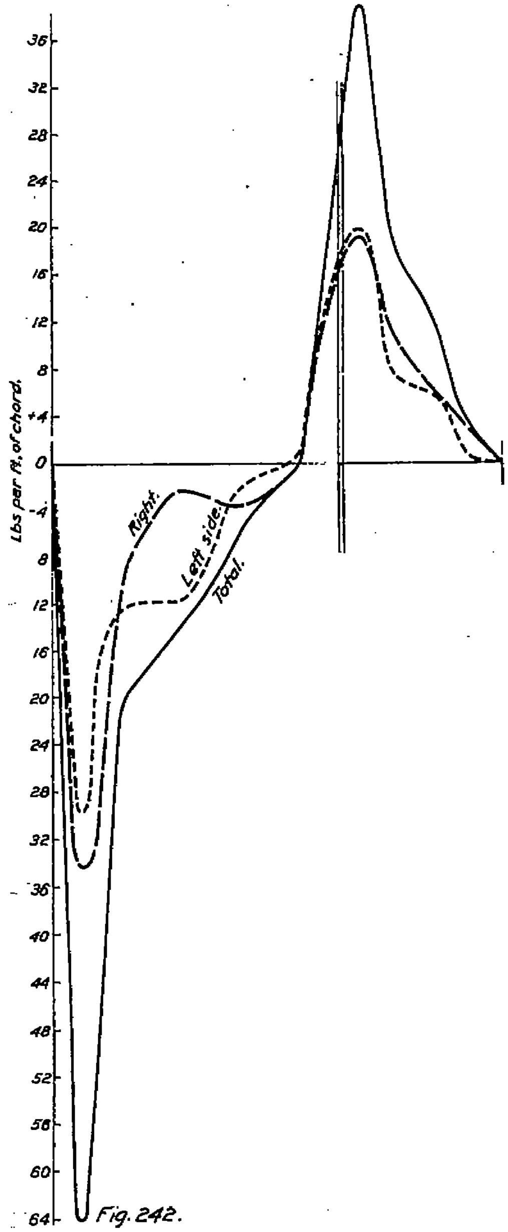


Fig. 242.

CASE II. 1400 R.P.M. 45 M.P.H.

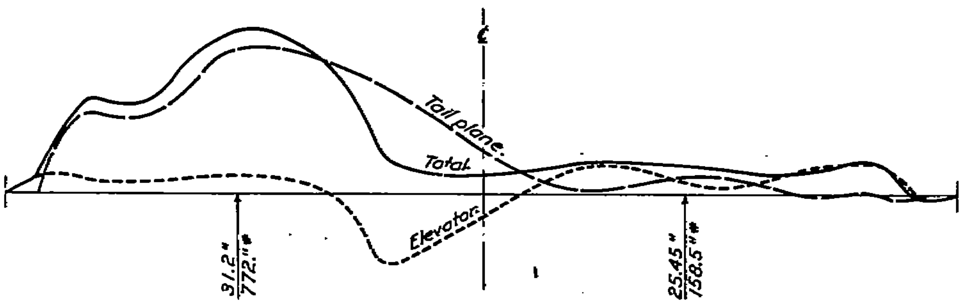


Fig. 243. Torque = Total moment = 613"# about ℄

CASE II. 1400 R.P.M. 50 M.P.H.

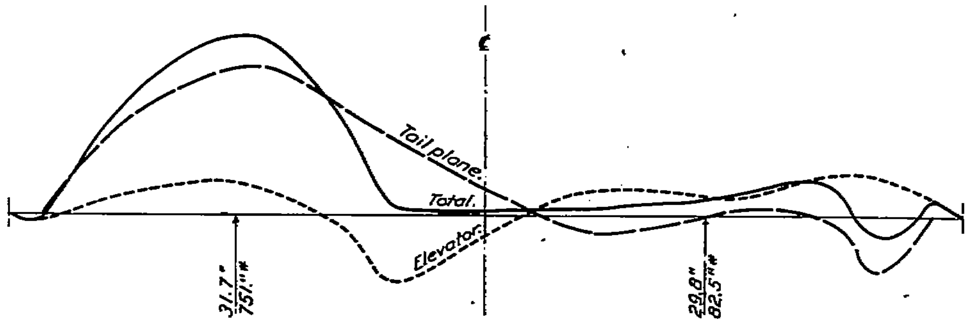


Fig. 244 Torque = Total moment = 668."# about ℄

CASE II. 1400 R.P.M. 60 M.P.H

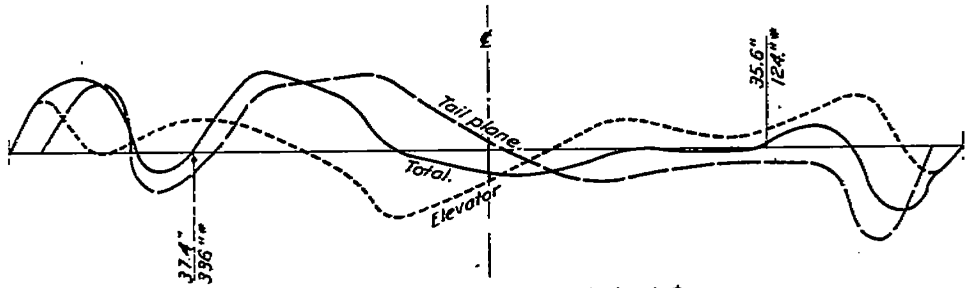


Fig. 245 Torque = Total moment = 460"# about ℄

CASE II. 1400 R.P.M. 70 M.P.H.

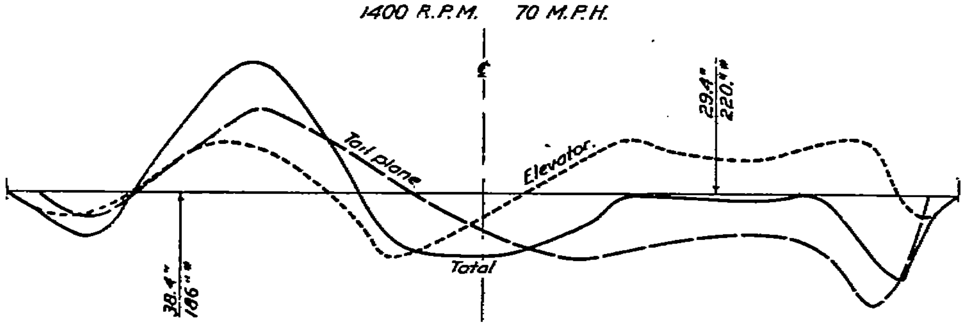


Fig. 246. Torque = Total moment = 406"# about ℄

Views of tail from rear.

CASE II. 1400 R.P.M. 80 M.P.H.

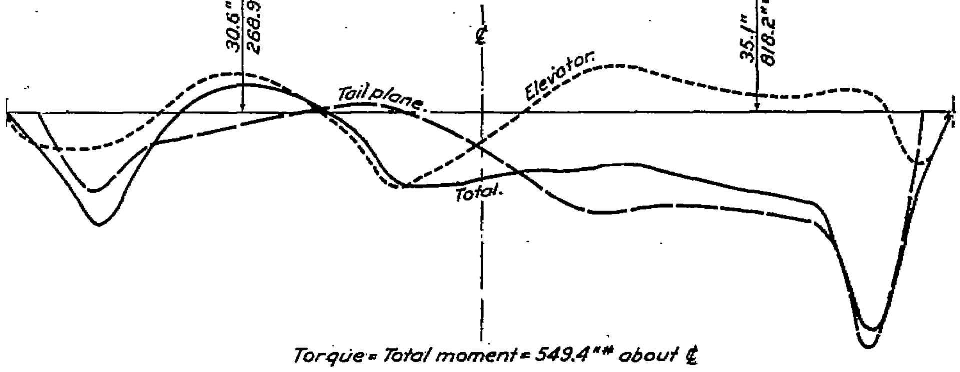


Fig. 247. Torque = Total moment = 549.4"# about ℄

CASE II. 1200 R.P.M. 60 M.P.H.

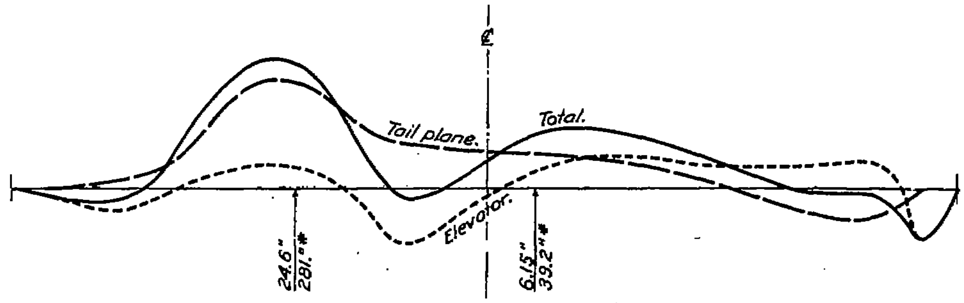


Fig. 248 Torque = Total moment = 242."# about ℄

CASE II. 900 R.P.M. 60 M.P.H.

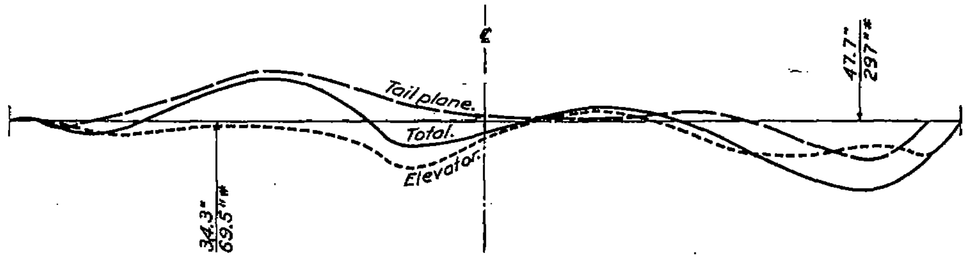


Fig. 249. Torque = Total moment = 366.5"# about ℄

CASE II 600 R.P.M. 60 M.P.H.

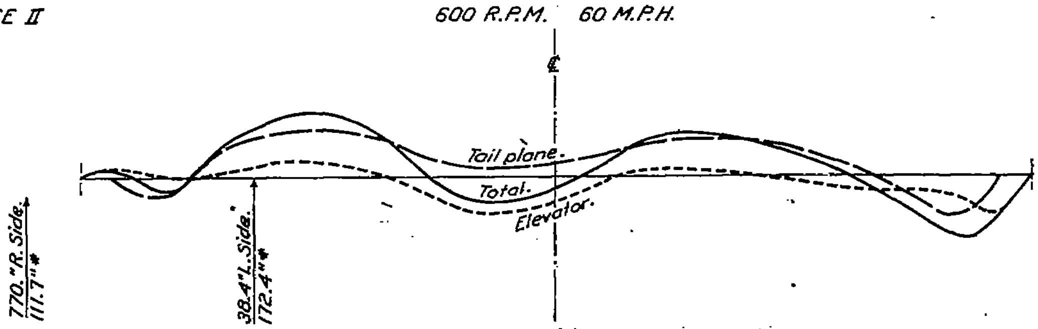


Fig. 250. Torque = Total moment = 284.1"# about ℄

Views of tail from rear.

CASE III. 1400 R.P.M. 45 M.P.H.

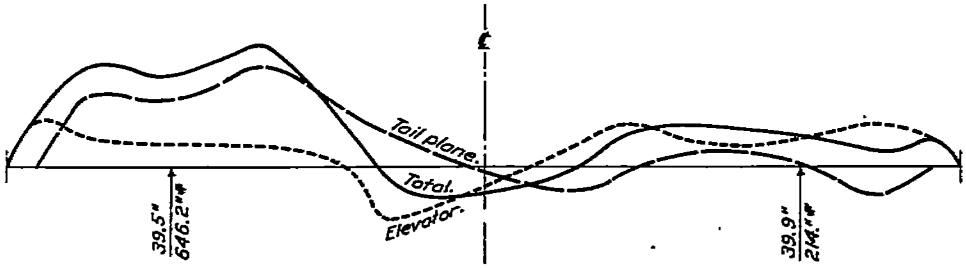


Fig. 251. Torque = Total moment = 432.2"# about ℄

CASE III 1400 R.P.M 50 M.P.H.

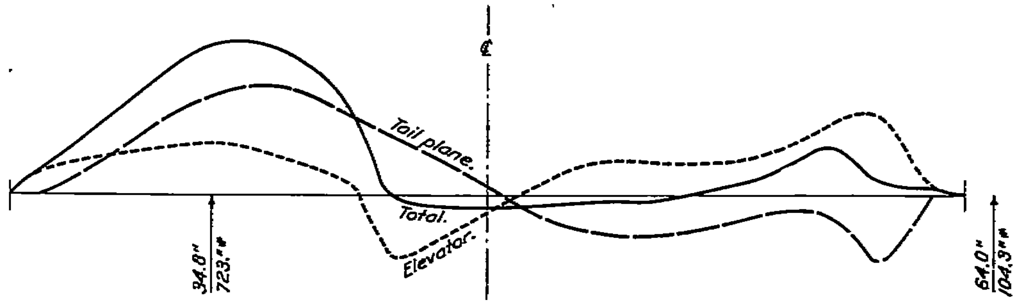


Fig. 252. Torque = Total moment = 619."# about ℄

CASE III. 1400 R.P.M. 60 M.P.H.

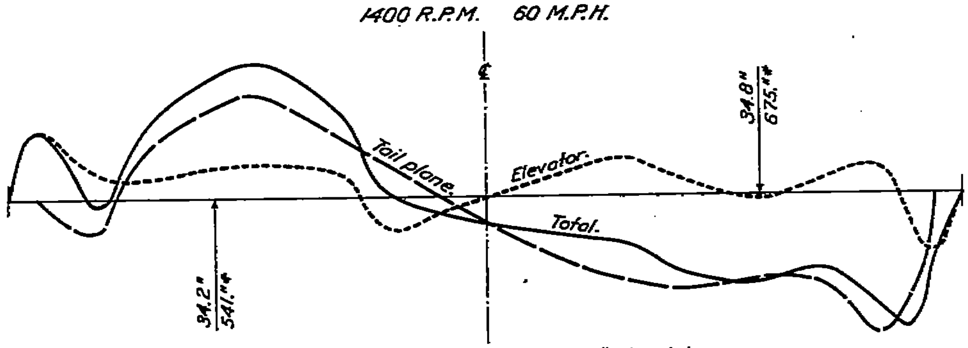


Fig. 253. Torque = Total moment = 1216"# about ℄

CASE III. 1400 R.P.M. 70 M.P.H.

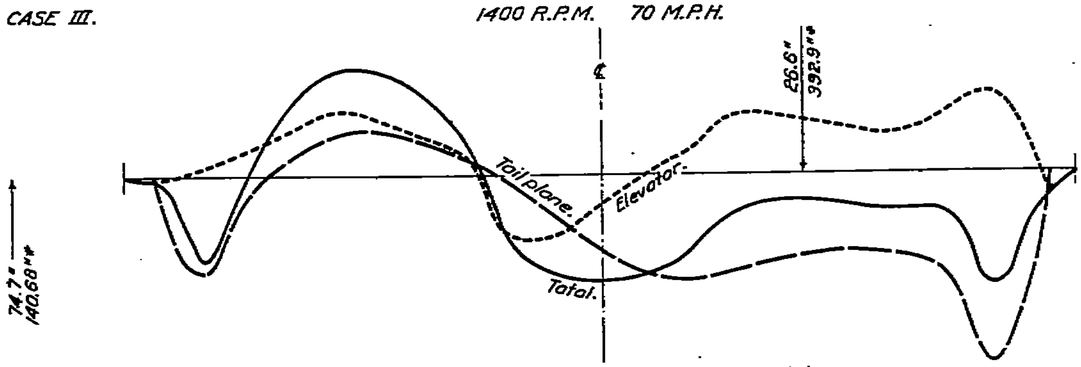


Fig. 254. Torque = Total moment = 533.5"# about ℄

Views of tail from rear.

CASE III. 1400 R.P.M. 80 M.P.H.

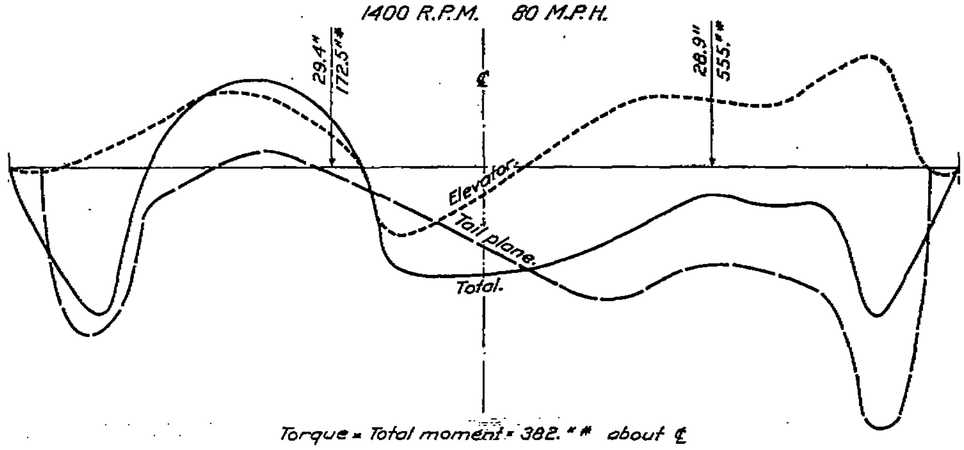


Fig. 255. Torque = Total moment = 382."# about ℄

CASE III. 1200 R.P.M. 50 M.P.H.

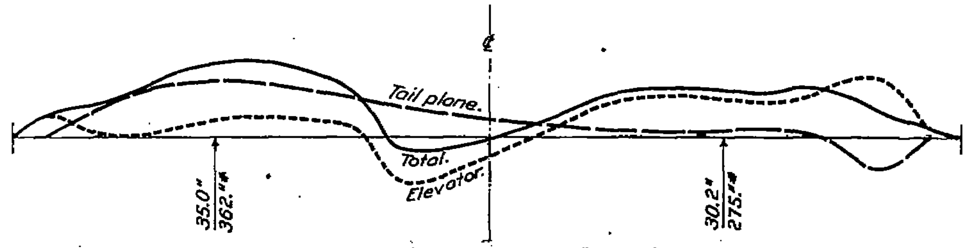


Fig. 256. Torque = Total moment = 87"# about ℄

CASE III. 900 R.P.M. 50 M.P.H.

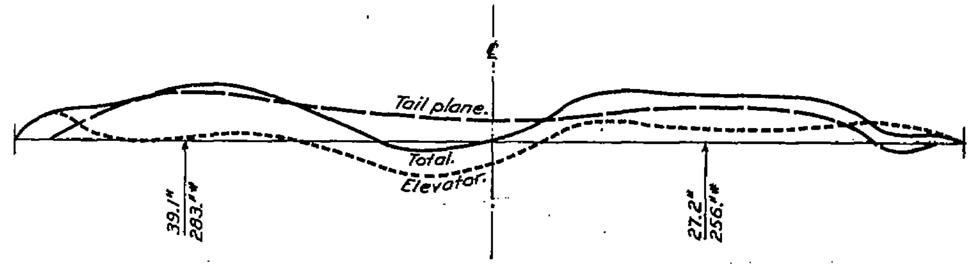


Fig. 257. Torque = Total moment = 27"# about ℄

CASE III. 600 R.P.M. 50 M.P.H.

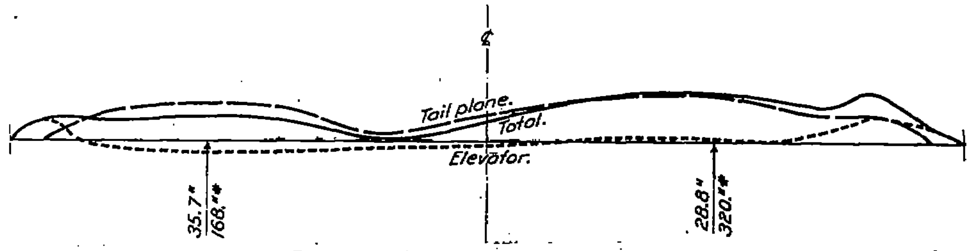


Fig. 258. Torque = Total moment = -152."# about ℄

Views of tail from rear.

CASE V. 1400 R.P.M. 45 M.P.H.

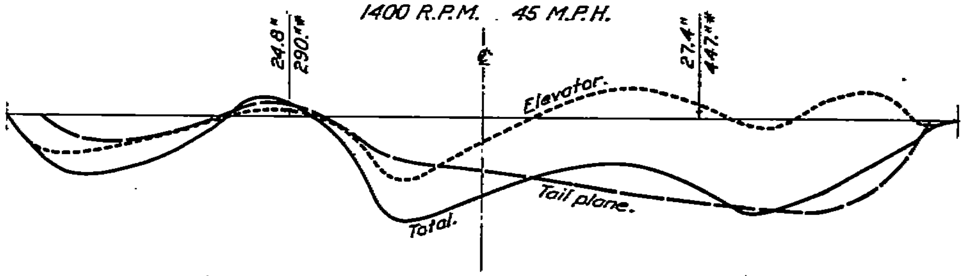


Fig. 259. Torque = Total moment = 157"# about ₵

CASE V. 1400 R.P.M. 50 M.P.H.

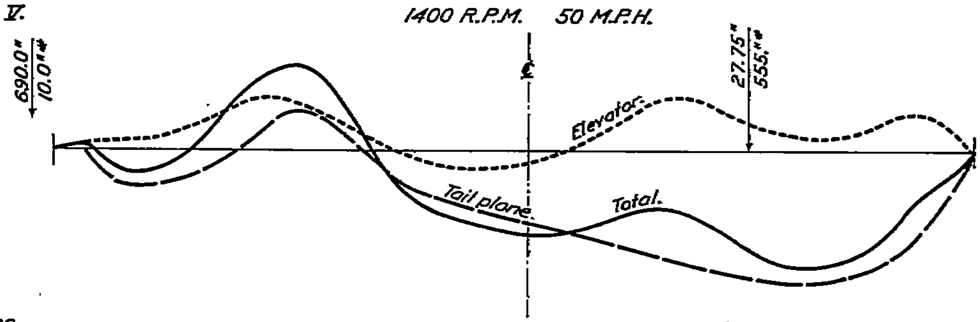


Fig. 260. Torque = Total moment = 545."# about ₵

CASE V. 1400 R.P.M. 60 M.P.H.

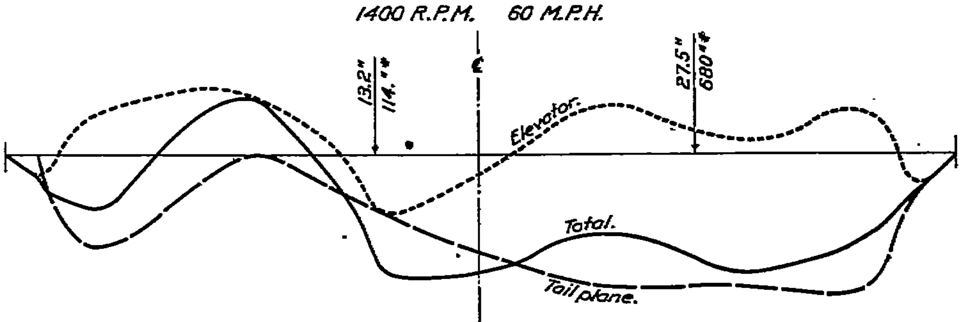


Fig. 261. Torque = Total moment = 566."# about ₵

CASE V. 1400 R.P.M. 70 M.P.H.

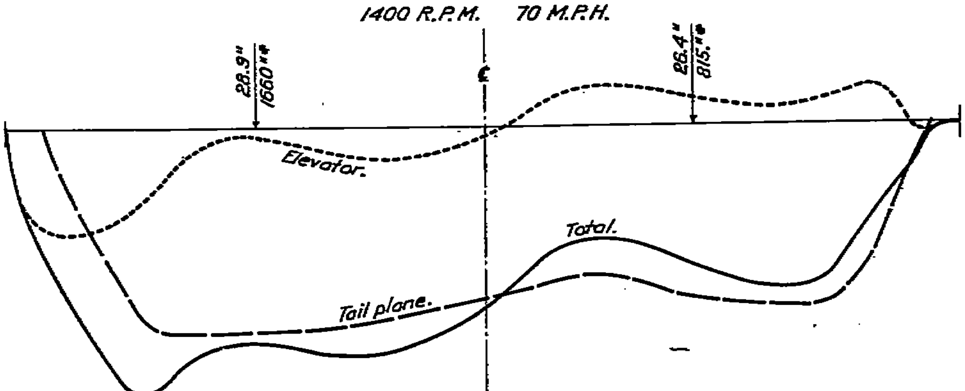


Fig. 262 Torque = Total moment = −845"# about ₵

Views of tail from rear.

CASE V.

1400 R.P.M. 80 M.P.H.

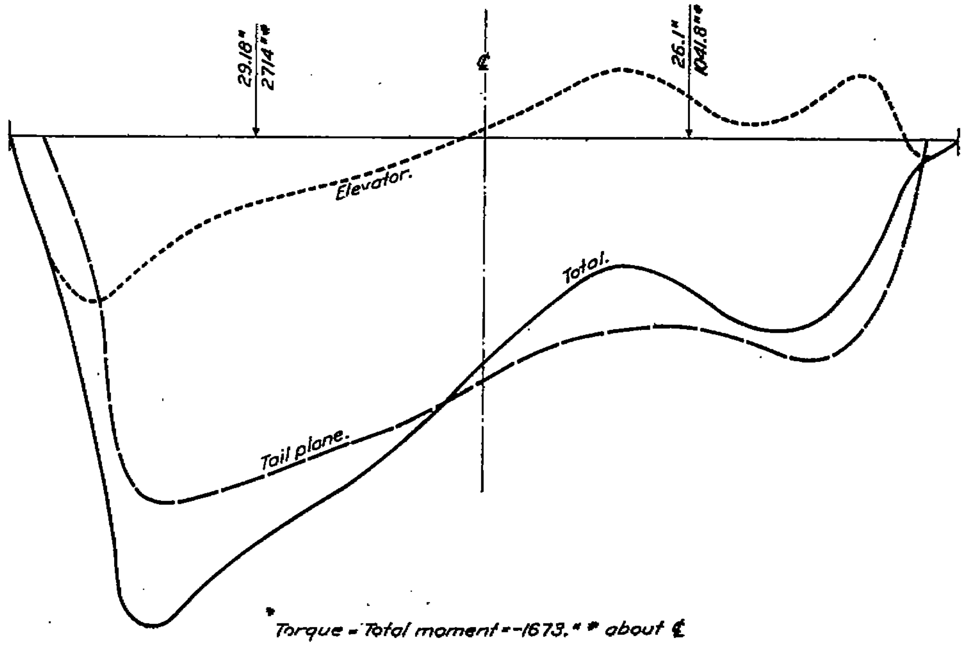


Fig. 263.

Torque = Total moment = -1673."# about ℄

CASE IV.

1400 R.P.M. 80 M.P.H.

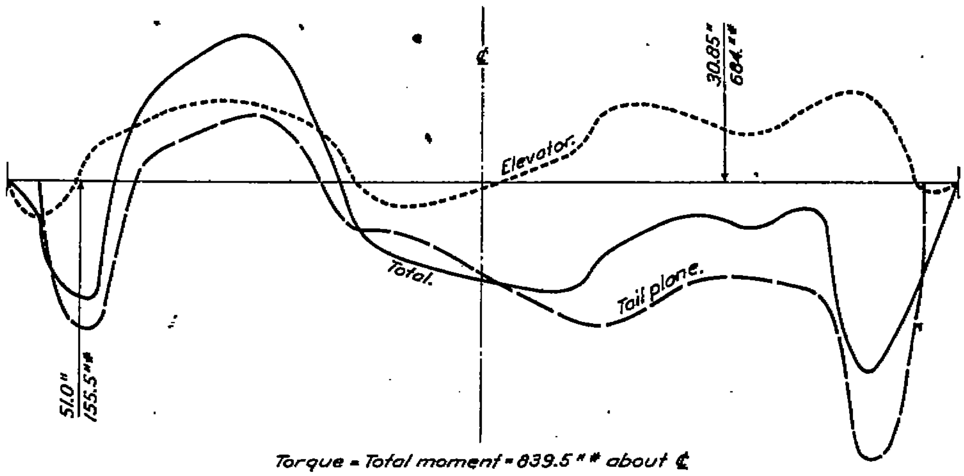


Fig. 264.

Torque = Total moment = 839.5"# about ℄

Views of tail from rear.